African Forage Plant Genetic Resources, Evaluation of Forage Germplasm and Extensive Livestock Production Systems

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PROCEEDINGS OF THE THIRD WORKSHOP
HELD AT THE INTERNATIONAL CONFERENCE CENTRE
ARUSHA, TANZANIA, 27–30 APRIL 1987

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by the

PASTURE NETWORK FOR EASTERN
AND SOUTHERN AFRICA (PANESA)

DECEMBER 1988

International Livestock Centre for Africa
P.O. Box 5689, Addis Ababa, Ethiopia

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Edited by B.H. Dzowela

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PREFACE

These proceedings include five opening and keynote addresses which provide introductory remarks on the activities of the Pasture Network for Eastern and Southern Africa (PANESA) in its regional attempts to enhance research and development of ruminant livestock feed resources. These introductory remarks are followed by papers on the themes of the workshop "African Forage Plant Genetic Resources" on which there are four papers presented. On the second theme "Forage Germplasm Evaluation" there are 16 papers presented and finally on the theme "Extensive Livestock Production Systems" there are 21 papers.

As a workshop organiser and editor of the proceedings, I would like to pay tribute to all authors and especially those who presented the papers at Arusha, Tanzania. From their contribution it was possible to record success in this workshop which fostered information exchange and cooperation among the many individuals of diverse interests who attended. Many individuals from Tanzania made significant contributions to the success of the workshop. I would like to thank particularly Prof. A.B. Lwoga in his role as Chairman of the Tanzania Forage Resources Network for giving the local support and the publicity the workshop received. All members of the PANESA Network Steering Committee carried out their support-role in a most helpful and professional manner. The administrative machinery at ILCA Nairobi merit special mention for their work with hotel and travel arrangements.

Preparation of this document involved several individuals who made significant contributions and all these deserve acknowledgement. Dr. Peter de Leeuw gave a critical view to some papers, Mrs. Eva Ndavu and K.S. Buigutt helped with proofreading and technical editing. Secretaries, Mrs. Angela Kiura and Josphine G. Njuki patiently put in so many wordprocessing/typing hours. Finally, the assistance of the Information Section of ILCA HQ in publishing the proceedings is gratefully acknowledged.

Ben H. Dzowela
PANESA COORDINATOR

TABLE OF CONTENTS

PREFACE iii

OPENING CEREMONIES

WELCOME ADDRESS - A.B. Lwoga 3

OPENING STATEMENT - Jackson A. Kategile 6

OPENING ADDRESS - J.C. Tothill 7

OPENING ADDRESS - Hon. Sumaiye 8

KEYNOTE ADDRESS - J.K. Kyambwa 12

SESSION I: AFRICAN FORAGE PLANT GENETIC RESOURCES

Some thoughts on the collection, introduction and evaluation of pasture legumes in Zimbabwe - J.N. Clatworthy and C. Madakadze 21

Review of range and pasture plants in Botswana - G. Tacheba and A. Moyo 37

Distribution of potential forage plants in Malawi - H.D.C. Msiska, J.T. Munthali and B.H. Dzowela 46

The distribution of *Sesbania* species in the PANESA region - J.F.M. Onim and B.H. Dzowela 54

SESSION II: FORAGE GERMPLASM EVALUATION

Forage germplasm at the International Livestock Centre for Africa J. Hanson and J.R. Lazier 69

A review of the potential of *Brachiaria* species as forage crop for livestock in Tanzania - N.A. Urio, S.V. Sarwatt and E.J. Mtengeti 74

Evaluation of the potential of some common forage germplasms in Mauritius - D. Jotee 81

A review of forage germplasm introduction and evaluation in Uganda - G.S. Byenkya 91

SESSION III: EXTENSIVE LIVESTOCK PRODUCTION SYSTEMS

Livestock production systems in Chokwe, southern Mozambique - J. Timberlake	237
Production of the Malagasy extensive livestock - J.H. Rasambainarivo and R. Razafindratsita	251
The prediction of rangeland production from rainfall data in arid and semi-arid Eastern Africa - P.N. de Leeuw and R. Nyambaka	260
Productivity of beef steers under rangeland conditions in a semi-arid area of Kenya - H.L. Potter	269
Classification of Kenya rangeland - M.O. Olang	286
Identification and ranking of production constraints in agropastoral systems of Machakos district in Kenya - A.W. Mukhebi and A.M. Gitunu	298
Relationship between phytomass productivity, animal forage preference and environmental factors on semi-arid grazed and ungrazed key range plants in Tanzania - M.M.S. Lugenja, R.N. Mero and A.R. Kajuni	310
Grazing behaviour of Maasai cattle - P.P. Semenye	325
The role of body weight changes and other factors in the control of fertility of beef cattle at Athi River Ranch, Kenya - E.K. Odhuba	331
The role of water pulses on the productivity of savanna ecosystems in Kenya - E.K. Maranga	365
Nutritional values of the diets of Maasai cattle - P.P. Semenye	373
Livestock feeding potentials, constraints and possible improvements in the semi-arid areas of Central Tanzania - A.J. Kitalyi and M.A. Kabatange	383
The potential of pasture legumes and their role in improving farming practices under extensive livestock production systems in Zambia - J. Kulich	394

Land-use changes in ranches which were set up in marginal areas of Kenya - M.O. Olang and T. Njoka 401

A strategy of livestock research adapted to semi-arid small-scale mixed farming system - the Katumani experience - S. Tessema, E.E. Emojong, M. Maluti and P.N. de Leeuw 405

Legume-based cropping: A possible remedy to land tenure constraint to ruminant production in the subhumid zone of Central Nigeria - G. Tarawali, M.A. Mohamed-Saleem and R. von Kaufmann 417

Role of crop residues as livestock feed in Ethiopian highlands - Daniel Keftasa 430

Nutrient quality of forages in Ethiopia with particular reference to mineral elements - E. Kabaija and D.A. Little 440

Effect of pasture mineral levels on extensive cattle production in Kenya - A. Abate 449

Effect of season, fertilizer application and age of regrowth on mineral content of guinea grass (*Panicum maximum* Schum) and Giant Star grass (*Cynodon nlemfuensis* Chedda) - E. Kabaija and D.B. Smith 458

Research needs for forage development in Ethiopia - the Fourth Livestock Development Project strategies - Alemayehu Mengistu and A. Robertson 468

List of Participants 483

OPENING CEREMONIES

WELCOME ADDRESS - A.B. Lwoga
Chairman of PANESA's Working Committee and
Chairman of the Executive Committee of the
Tanzania Forage Resources Network

On behalf of the PANESA Working Committee, on behalf of the Executive Committee of the Tanzania Forage Resources Network and on my own behalf, I should like to take this opportunity to warmly welcome you all to this ceremony which marks the beginning of the PANESA Workshop and Annual General Meeting for the year 1987. As a Tanzanian citizen, it is my great pleasure and privilege to welcome all the foreign workshop participants to Tanzania, and to Arusha in particular. I am not a resident of this part of Tanzania, but I know that Arusha town is very famous for its hospitality and, also, that the surrounding countryside boasts of some of the rarest and most wonderful game sanctuaries in the world. You are, therefore, most welcome to utilise this opportunity, over and above the workshop business, to learn a bit about Tanzania by exploring Arusha and the surrounding countryside.

A word of special welcome is due to our Guest of Honour today, the Honourable Sumaiye, Deputy Minister for Agriculture and Livestock Development. I am most delighted that he has been able to accommodate this event in his very busy schedule of activities, and also that he has been able to come, to officiate at this ceremony. I should, therefore, like to place on record my deep appreciation to the Deputy Minister for the honour he has accorded us by agreeing to perform this important function in the history of PANESA.

Mr. Guest of Honour, it is pertinent on this occasion to take a brief look at PANESA's origin and tasks. The Pasture Network for Eastern and Southern Africa has its roots in a workshop which was held at Harare in Zimbabwe in September, 1984 and attended by pasture and livestock experts from eleven eastern and southern African countries. Having realised that inadequate nutrition was the single most important constraint to livestock production in the countries represented, the workshop resolved to form a network which would strive to find solutions to the problems affecting pasture production and, consequently, the livestock industry in the Eastern and southern African region. PANESA was launched in November 1984 with the overall aim of improving the effectiveness of pasture research in participating countries and expediting the application of improved technology by farmers and graziers at all levels of management.

What is the nature of the problems that PANESA has committed itself to solve? A glance at the past and present performance of the ruminant livestock industry in eastern and southern Africa throws some light on the urgency and immensity of PANESA's tasks. Eastern and southern Africa as a region holds nearly 86 million head of cattle or 51% of the total cattle population on the African continent. The region, however, produces a mere 38% of Africa's bovine meat and only 33% of Africa's cow milk. The annual herd offtake is estimated to be 10%, representing about 143 kg of slaughter weight per head, compared with an offtake of 34% and a slaughter weight of 218 kg per head for the developed countries. The average milk yield is estimated at 425 kg per year per cow, compared with 3,217 kg per year per cow in developed countries. Overall livestock production is so low that it hardly meets the human requirements for livestock products in the region. One consequence of this situation has been an increase in imports of livestock and livestock products over the years.

We in PANESA believe that inadequate nutrition for the animals is one of the main factors accounting for the low productivity of livestock in the region. The animals subsist largely on natural pastures whose vegetation is not only scanty, but also of low quality. In the eastern and southern African region, natural pastures occupy 34% of the total land area while cultivated pastures occupy a mere 6%. In the developed countries corresponding proportions are 23% for natural pastures and 12% for cultivated pastures. The tasks of PANESA, urgent and immense as they are, involve removing the nutrition bottleneck through the generation and/or adaptation and application of appropriate technology.

Mr. Guest of Honour, since its formation in November 1984, PANESA has carried out the following activities in pursuit of its objectives:

1. It has started a newsletter, the "PANESA Newsletter", which is a medium for the exchange of ideas and experiences among all those interested in pasture and livestock research and development.

2. It organised a workshop in Nairobi, Kenya in November, 1985 on the theme "Feed Resources for Small Scale Livestock Producers".

3. It organised a training course for young early career scientists and pasture technicians in "Forage Plant Introduction and Initial Evaluation" in Ethiopia in October, 1986.

4. It has started a collaborative pasture introduction and evaluation programme in which national research institutes participate in experiments that are coordinated on a regional or sub-regional basis.

Mr. Guest of Honour, the workshop you will be opening in due course is yet another milestone in PANESA's efforts in the long march towards its objectives. The theme of the workshop, which arose from the Nairobi workshop in November, 1985, consists of three topics, namely:

1. African forage plant genetic resources. This aims at taking an inventory of important forage plant genetic resources in the region.

2. Germplasm evaluation. This seeks to take stock of national research efforts in forage germplasm evaluation in the region.

3. Extensive livestock production. This aims at reviewing the state of the art in the diverse extensive livestock

production systems in the region with the objective of identifying common problems and generating strategies to improve the productivity of the systems.

The workshop has drawn more than 60 participants from 14 member countries, namely: Botswana, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Somalia, Swaziland, Uganda, Zambia, Zimbabwe and the host, Tanzania. The workshop has also drawn participants from a number of international research agencies including the International Development Research Centre (Canada) and the International Livestock Centre for Africa (based in Addis Ababa).

Mr. Guest of Honour, this workshop would not have materialised and, indeed, PANESA would not have come into being in 1984 had it not been for the generous financial, technical and logistical support of international research agencies sympathetic to the cause of PANESA. The International Development Research Centre organised and financed the Harare Workshop in 1984 and further financed PANESA's first budget, whose activities include this workshop. The International Livestock Centre for Africa has provided the headquarters as well as back-up facilities and services for PANESA.

I take this opportunity of paying tribute to the fundamental and far-reaching role these two organisations have been playing in establishing PANESA and, thereby, helping to build up national capabilities in pasture and livestock research and development in PANESA member countries. I wish to express my sincere hope that their commitment will endure, and also that other international agencies will join hands with PANESA in improving livestock productivity through better livestock nutrition in Eastern and southern Africa.

Mr. Guest of Honour, it is with greater pleasure, honour and privilege that I now invite you to officially open this workshop.

OPENING STATEMENT - Jackson A. Kategile
IDRC, Nairobi

Honourable Sumaiye, Deputy Minister for Agriculture and Livestock Development, Ladies and Gentlemen:

It is certainly a great pleasure to be with you in Arusha for the third Workshop on Pastures in Eastern and Southern Africa. For some of us, this is also our third time to be together in a similar forum. But to those who are not familiar with IDRC, Mr. Chairman, I request a minute to enable me to introduce the organisation.

IDRC is a corporation created by the Parliament of Canada in 1970 to stimulate and support research in developing countries for the countries' own benefit. IDRC is funded entirely by the Canadian Parliament to which it reports annually. Its operations are guided by an international 21-member Board of Governors. IDRC has its headquarters in Ottawa with regional offices in Singapore (Southeast Asia, East Asia and the Pacific), New Delhi (South Asia), Nairobi (Eastern and Southern Africa), Cairo (West and Central Africa) and Bogota (Latin America and Caribbean). IDRC gives support to developing countries to carry out research in areas of agriculture, health sciences, social sciences, communication and information. I am in the division of agriculture, food and nutrition sciences within which animal sciences is encompassed. The Animal Science Sub-program in Eastern and Southern Africa gives priority to research aimed at improving the traditional livestock production systems, including nutrition, pastures and socio-economics. It is therefore, not surprising that IDRC has been associated with your interests and efforts in pasture improvement through the Pasture Network for Eastern and Southern Africa (PANESA). The network has grown from a dream to reality. In 1984, an idea was floated, today ILCA is the coordinating agency and an active committee is guiding the activities of PANESA. A full-time coordinator is now in place. The noble aims within the umbrella of PANESA include:

1. Strengthening pasture research capabilities.
2. Procuring, disseminating and exchanging forage germplasm.
3. Evaluating the germplasm procured.
4. Developing appropriate technologies for traditional systems.
5. Collecting, disseminating and exchanging information.

PANESA has attracted the attention of several agencies because of the important goals that you have set for yourselves, and because the modality of organisation is bottom-up thus facilitating the inputs of scientists from the region into an ILCA-coordinated network. PANESA also encourages national networks.

I do hope that this workshop will enable you to exchange information and experiences. Further, I do hope that you will take time to discuss the regionally coordinated research activities. In drawing up your plans for regional research activities you may wish to bear in mind that there are some funds (though limited) which can be made available for national activities, and ILCA can assist you in:

- research protocols
- data processing
- supply of germplasm
- training of scientists and technicians
- supply of some literature.

It is certainly advantageous to draw upon ILCA's resources.

As it is not my intention to take too much of your time, I would like to reiterate that IDRC is proud to be associated with PANESA and looks forward to a fruitful co-operation.

OPENING ADDRESS - J.C. Tothill
Head, Plant Sciences Division
International Livestock Centre for Africa

Mr. Deputy Minister for Agriculture and Livestock Development, the Commissioner for Livestock Development, Chairman Professor Lwoga, Ladies and Gentlemen:

It is a pleasure for me to be here today: firstly to pay my respects to you, Mr. Deputy Minister, on behalf of the International Livestock Centre for Africa, and secondly to compliment our hosts Professor Lwoga and conference organiser Dr. Dzowela on the organisation of this meeting, which is my first.

ILCA has been honoured and challenged by the PANESA membership, through its elected Working Committee, by being invited to be the technical partner complementing IDRC's financial partnership in this network. We have welcomed this offer because we sincerely believe we have something to offer PANESA and its membership, but we also have something to take and that is the wisdom of the membership in helping us to more effectively shape our own programme. That is, we see the interaction as two-way.

As some of you may know ILCA is presently going through a process of self examination and programme redefinition. This is calling for much greater interaction with national scientists, with much of this coming through the links that networks like this provide. The effectiveness of technology transfer can be magnified many-fold through the networking approach.

We have a strong commitment to the dual role that forages can play in both improved animal production through nutrition and crop production through better soil fertility. The two are linked through the animals that most African farms maintain.

We therefore have great pleasure in coming together to discuss these issues here in this beautiful, and I am sure bountiful, region of Tanzania, and we thank you, Sir, for this opportunity.

OPENING ADDRESS - Hon. Sumaiye
Deputy Minister for Agriculture
and Livestock Development

Mr. Chairman, Distinguished Delegates, Ladies and Gentlemen:

I feel greatly honoured to have been invited to open this workshop on behalf of Hon. Jackson Makweta, the Minister for Agriculture and Livestock Development, which will be dealing with three themes namely:

1. African forage plant genetic resources
2. Germplasm evaluation
3. Extensive livestock production.

The workshop bears special significance for Tanzania since livestock production plays an important role in the socio-economy of the country.

Thus, on behalf of the United Republic of Tanzania and, on my own behalf, I would like to thank PANESA for deciding to hold this workshop in Tanzania and the organisers for the successful preparation of the workshop. I am glad to note that the workshop has drawn participants from the Eastern and southern African countries and from outside Africa. This, I believe, will provide a unique opportunity for sharing experiences for the common goal of happiness and progress of mankind in Eastern and southern Africa. I would like, in this connection, to take this opportunity again to warmly welcome all the foreign colleagues to Tanzania. It is my sincere hope that you will find your stay comfortable and also that your programme will allow you some time to see and learn more about Tanzania.

Mr. Chairman, I believe I do not need to remind this audience of the seriousness of the food crisis facing Africa. Suffice it to say that our governments are concerned about the consistent decline in food production throughout the continent over the past two decades, a period in which there have been marked increases in food production in the other continents, including the Green Revolution in Asia. Our governments are also worried about the upward trend in population growth in Africa, as contrasted with the downward population growth trends in all the other continents over the same period. The combination of these two scenarios has meant that our people, with each passing year, are becoming poorer, hungrier and less well nourished. It has also meant that our governments have, over the years, had to import increasing amounts of cereal grains and livestock products to make up for deficits in domestic food production. In short, the resulting situation has posed a real threat to the continent's political and socio-economic survival.

Can this threat be averted? Mr. Chairman, my answer is yes, even though, I know, the task will not be easy. For in the words of Dr. Carl Eicher, a prominent agricultural economist (Professor of Agricultural Economics at Michigan State University, USA), "Africa's agricultural production must be doubled within the next 15 to 20 years to keep up with population growth rates of 3 to 4%". Mr. Chairman, it is my strong belief that solutions for Africa's agrarian crisis will have to be found within Africa, and not from outside Africa. Effective crop and livestock production strategies for the diverse ecological and farming systems in Africa cannot be prepared in Europe or America. Such strategies must emerge from Africa, prepared from results of intensive, long-term research on agricultural production constraints. For, while it is possible and useful to transfer or adapt some existing technology from elsewhere, much of the knowledge needed for agricultural production will be locale-specific, and will have to be generated locally. It is in this context that I think highly of the objectives and activities of your network which are:

1. To strengthen national pasture research capabilities primarily through training and data analytical facilities.

2. To procure, disseminate and exchange pasture plant germplasm in the region and from international sources.

3. To evaluate promising pasture plant species/strains for adaptation and production in different ecological zones and agricultural production systems.

4. To develop appropriate pasture production technologies that can be integrated into the prevailing livestock production systems.

5. To collect, disseminate and exchange information.

Mr. Chairman, PANESA is a new network aiming, to use your own words, at improving effectiveness in pasture research in participating countries and expediting the application of improved technology by farmers and graziers at all levels of management. I hope you will keep the network new in its approach towards tackling Eastern and southern Africa's livestock and pasture problems. I hope you will learn from the experience of older professional networks and associations in Africa and avoid their mistakes. For example, due to financial constraints affecting most of our countries, the choice of research projects undertaken by many national research institutions and professional associations and networks has been inspired by donors. Such research does not, if at all, address the true and felt needs and constraints of the host countries and cannot therefore, generate technology that will help transform our agriculture.

Allow me to suggest, therefore, that PANESA should consider, as a matter of urgency, establishing livestock and pasture research priorities and plans within member countries and for the region as a whole. This will not prevent individual researchers from pursuing their own desires but it will, at least, provide guidelines for the allocation of scarce national resources and also for donors to respond to.

Another common weakness of our research systems has been that the results of research are often not accessible both to the end-users (livestock-keepers) and other researchers and scholars outside the boundaries of our countries or regions simply because they are reported in working papers and published in limited numbers of copies. It is my hope that PANESA will concern itself not only with the generation of improved livestock and pasture innovations but also with the adoption of such innovations by the livestock keeper in his environment.

Mr. Chairman, your network is meeting in Tanzania at a time when we are intensifying our efforts in agricultural development. One of our major concerns is to transform the livestock industry so that it can play a greater role in the socio-economy of the country. In particular, we would like the livestock industry to:

1. increase the *per capita* income of individuals engaged in livestock production, processing and marketing, with emphasis being placed on producers in the traditional sector;

2. increase the volume and quality of livestock products to service local industries using livestock products as raw materials as well as generate exportable surpluses and reduce import requirements;

3. increase the production, processing, and marketing of animal protein to meet national nutritional requirements; and

4. increase the use of drought animals, thereby reducing both the use of imported energy on the farm and the human burden.

Ruminant livestock are an important component of the livestock industry in Tanzania. They number over 12 million head of cattle and 10 million head of sheep and goats, distributed over approximately 45,900 sq km of mainly natural grassland. Over 99% of all the cattle, sheep and goats are owned by livestock keepers in the traditional, largely subsistence, sector. Despite the diversity of production systems, this sector has several characteristic features:

1. Grazing resources are utilised communally.

2. There is increasing encroachment on grazing land by arable farming which, combined with increasing livestock numbers over the years and periodic droughts, has led to serious land degradation.

3. Productivity of the livestock is low; with calving rates of less than 40%, calving intervals of about 2 years, calf mortality rates in the range of 25-40% and an offtake of less than 10%.

When we talk of transforming the livestock industry in Tanzania, we therefore, essentially mean a multiplicity of transformations in the traditional livestock sector:

- It means transforming the outlook of the livestock keeper from being a subsistence to a commercial producer.

- It means serious attempts to preserve the natural rangeland and improve its water resources, and prevent bush fires which destroy the ecology, fauna and flora.

- It means evolving production systems that not only utilize but also conserve grazing resources.

- It means evolving production systems that integrate livestock production with crop production.

- It means developing better adapted, higher yielding and more nutritious forage species.

- It means developing a more productive animal than the one available at present.

- It means establishing more effective production - marketing linkages in the pastoral areas.

- It means evolving land tenure systems that are consistent with improved production systems.

All I am trying to say, Mr. Chairman, is that transformation of the livestock industry in Tanzania and, I believe in most of the PANESA member countries, requires the successful application of a set of technologies appropriate to the millions of small livestock keepers in the traditional sector. The generation and application of these technologies is, I believe, a major need that PANESA must try to meet.

Obviously, this will require execution of long-term, multi-disciplinary research projects in which participants include not only research scientists, but also extension workers and livestock keepers as partners in a common endeavour. I am confident that this workshop, which has drawn livestock and pasture experts from within and outside Africa, will go a long way in formulating an agenda aimed at providing effective solutions to livestock and pastures in Eastern and southern Africa.

All that remains for me is to say how grateful I am to have been given this priceless opportunity to be with you this morning, and to wish the workshop all the success that it so rightly deserves.

I am very happy to declare the workshop open.

KEYNOTE ADDRESS - J.K. Kyambwa

Commissioner for Livestock Development
Ministry of Agriculture and Livestock Development
P.O. Box 9152, Dar es Salaam, Tanzania

Mr. Chairman, Distinguished PANESA members, Ladies and Gentlemen: It is indeed a great pleasure for me to have this opportunity through which I can share with you our ideas on pasture work and animal nutrition and the direction of such a discipline in Tanzania.

Secondly this meeting has additional importance not only in exchanging ideas but also in getting acquainted with scientists involved in this vital discipline in different sub-Saharan countries.

It is obvious that people coming from different parts of the Eastern and southern African region would have different experiences which can be shared with us. As you are all aware, present demand for food, grazing, fibre and fuel has increased beyond the limits that nature can provide unaided. Future demand for the land to produce these products will be even greater. The potential of the land to produce these products is set by the soil and climatic conditions and by the level of inputs and management applied to the land. Any overuse beyond these limits results in degradation beyond economic feasibility and subsequently yields decline, threatening the lives of the people in the countries, as it is happening now in sub-Saharan African countries.

Mr. Chairman, let me highlight the forage resources in Africa as a whole with examples of the constraints prevailing in Tanzania.

THE FORAGE RESOURCE

The forage plant resources of Africa are composed of forests, such as the Congo forests, woodlands/brushland and savannas which cut across the continent. In these communities, there exist numerous grasses and herbaceous plants which form the bulk of the livestock diets. These communities have been used to enrich the genetic pool of pasture plants, particularly grasses for other tropical countries.

In its natural state the African biome is quite delicate; its management requires the application of proper ecological principles to maintain the system. With an exception of the Congo forest, the woodland/brushland and grassland formations are typical rangelands of Africa and are very important to us. These rangelands are usually semi-arid and in most cases receive annual precipitation below 700 mm. However, their potential in livestock production is enormous. Much of this range resource remains under exploited.

In Tanzania there are 60 m ha of rangeland potentially suitable for livestock production but only 6m ha are currently utilised. Underutilisation of this resource is due to high tsetse fly infestation, poor management practices, lack of land tenure policy, inadequate water supplies, overgrazing and lack of markets.

Tsetse Fly Infestations

About 530 m ha are infested with tsetse flies. These areas cover the bulk of western and eastern Tanzania. Some pockets of tsetse also occur in northern Tanzania in the national parks and game reserves. Consequently livestock expansion has been limited by the presence of the flies and the lack of national policy for tsetse control.

Poor Management Practices

In the traditional livestock sector, which accounts for 99% of the total livestock numbers in the country, animal husbandry is poor, resulting in low calving, weaning and offtake rates, and high pre-weaning and herd mortalities.

Lack of Land Tenure

Most of the traditional grazing lands are owned publicly and grazed communally. There are no restraining measures on the number of animals an individual can keep. Under this communal tenure system, there is not enough motivation for an individual or group of individuals to invest in pastureland improvement programmes, or to maintain the quality of existing infrastructure.

Inadequate Water Supplies

Unreliable rainfall coupled with seasonal rivers, has necessitated conditioning the livestock to drink water irregularly. Prolonged dry seasons have made it impossible for the livestock to maintain their weights resulting in excessive unthriftiness of the animals. In severe cases prolonged dry seasons followed by severe forage shortages result in livestock deaths.

Overgrazing

There is a general inability on the part of the farmer to match the animals to the available forage. This has resulted in overstocking and subsequently overgrazing. This trend in turn is characterised by soil degradation. The consequences have been low herd fertility and high mortality rates.

Lack of Markets

Although the notorious killer diseases such as rinderpest have been under control, the quality of livestock accrued from these efforts are still below the standard required by the meat importing countries. In addition to this, there have been insufficient incentives locally to force the stock owners to sell the right proportion of their livestock. Consequently, the offtake rates have remained below 10%.

Further, a general lack of basic infrastructure such as dips, watering points, livestock development centres, markets, cattle handling facilities, dispensaries, etc. and pursuance of conflicting objectives on the use of land, all combined limit the widespread distribution of livestock.

The exploitation of the African forage plant resource will therefore depend on how fast our local scientists can realise appropriate interventions to mitigate the above constraints. The testing and adaptation of simple techniques to improve the productivity of the forage resource should provide a challenge to research scientists.

The overgrazing trend characteristic of the heavy livestock areas in Tanzania imply that the present pasture plants cannot withstand grazing under a communal land-use system. Research scientists in pastures are therefore confronted with the task of providing plants that are going to establish easily, persist under drought conditions, provide nutrients to livestock as well as having a soil stabilising characteristic.

In Tanzania, considerable efforts have been given to pasture research since the early 1930s, as animal nutrition became evident as a limiting factor to livestock production. Up to 1970 findings on cases of range productivity, manipulation of species introduction and evaluation and pasture agronomy, had been realised through zonal research centres. These findings were carried out by non-African scientists on short contracts; as a consequence, they have been of little practical application.

The bulk of our range is still under communal land use system. Past research also suffered from lack of coordination, direction, continuity and a responsible institution for pasture research.

Mr. Chairman, my country has embarked on rehabilitating the present research institutions, such as the Tanzania Livestock Research Organization (TALIRO), with more support in terms of animal diseases, tsetse, trypanosomiasis and pasture research.

The Pasture Research Institute, to be established at Kilosa, will be charged with the responsibilities of carrying out research in better methods of range resource use to farther animal 'productivity in the country. The immense responsibility will be the focus of discussion in the three-day workshop.

Mr. Chairman, having discussed briefly the status of pasture research in my country, you will bear with me and look briefly at the food and livestock situations. Food and agricultural output has not kept pace with the increasing population due to many factors which may not be different from those operating in other PANESA member countries. These include: lack of infrastructures (particularly feeder roads) and low level technology in agriculture, livestock and fisheries. These problems have become acute as a result of long-standing input supply, ineffective extension services, lack of skilled manpower and inability of past research efforts to make a break in key areas.

Agriculture is still the backbone of our country's economy, contributing well over 50% of the foreign exchange earning. However, the livestock sector's contribution to the economy as compared to arable farming, has for a long time remained insignificant.

Food crop production during 1972-1980 increased at 5% per annum compared with 3.5% decline in cash crop production. The increase in food crops was due to increase in the amount of acreage brought into production while yield per unit area actually declined.

Tanzania's present livestock population stands at 13 m cattle, 5.8 m goats, 3.8 m sheep, 130,000 pigs and approximately 25 m poultry. Its distribution follows the pattern of human population and is inversely correlated with the areas infested with tsetse flies. The main areas of cattle raising are the dry open grasslands or wooded grasslands where precipitation is marginal for crop cultivation. Large concentrations are in the northern and western parts of the country and the population is expanding in the southern highlands.

In terms of livestock per head of the human population, Tanzania is one of the most significant livestock rearing countries in Africa. Yet the average consumption level of animal protein per person is only 22% to 33% as estimated by the Food and Agriculture Organization. There is a marked difference in consumption level between rural and urban populations, as well as between the regions.

In order to increase the livestock sector's contribution to the national economy and increase consumption levels of animal protein in the short and long term, my Government plans to develop the traditional, commercial beef and dairy herds.

DEVELOPMENT OF THE HERDS

Traditional

Some 85 to 90% of the national cattle herd is under stock owner cultivators. Livestock development strategies under stock-owning cultivators will emphasise both livestock and crop production. Experience has shown that as crop production declines, livestock population also declines and vice versa. The remaining 10 to 15% of the national herd is owned by pastoralists who occupy the grasslands of Serengeti, the woodland and wooded grassland of the Maasai Steppe. This production system is characterised by ownership of large numbers of stock, lack of livestock movement control, communal grazing system, traditional husbandry practices, absence of livestock records, rudimentary identification methods, estimation of cattle numbers and continuous breeding. Selection and culling is seldom done. There is no routine disease control programme, except for the nationally coordinated campaigns, like rinderpest. Traditional pasture and range management methods and non-specialised grazing systems are practised. When developed, it will be able to play its part in raising the animal protein consumption levels to 4.3 kg protein per capita.

The development would require proper land-use plan and provision of livestock improvement packages. This would be achieved by settling farmers in villages and development of village ranches followed closely by the application of principles of range management. The overall development of the traditional herd require that it increases by 69% in order to meet the year 1990 national beef targets, and a further 50% increase would be needed to meet the year 2000 demand. To meet these, annual offtake rate targets would have to increase from 10 to 12% by 1990 and 13% by year 2000. Carcass weights would have to increase from 100 to 120 kg.

Commercial Beef Herd

Mr. Chairman, Ladies and Gentlemen, the commercial beef herd is only a small portion of the total cattle population run independently by the NARCO, TSC and ASC. However, the Government has been charged with the responsibility of:

1. Building up an improved quality beef herd which will provide a source of stock for the traditional sector;

2. Producing improved quality beef for home consumption and for export;

3. Acting as a catalyst for improved ranching techniques for the traditional sector;

4. Fattening feeder steers purchased from the traditional sector, thus increasing the overall national meat production; and

5. Providing certain technical and training services where possible.

The development strategy followed includes expansion of the ranches and intensification of some of the existing ranches. The expansion strategy has realised over 15 ranches. Many of the ranches under NARCO are low-cost extensive ranches. Some of the mature ranches have been intensified by investments in the development of the environment and water. Consequently, they have reached their production targets as manifested in their average production coefficients:

- calving rate 56%,
- weaning rate 50%,
- pre-weaning mortality rate 9%,
- herd mortality 7%,
- offtake rate 15.4%.

The herd offtake rate will have to increase by 15 to 20% and carcass weight from 150 kg to 165 kg in the long term (1990-2000) to meet the projected beef demand as required by the National Food Strategy of 1982.

Dairy Herd

Mr. Chairman, Ladies and Gentlemen, in the analysis of the livestock sector, the role played by the dairy herd in the nutrition of our people and the economy of the country has not been forgotten. Development of the herd which comprises commercial dairy farms, traditional cattle owners and the smallholder dairy farms, aims at stimulating dairy production to substitute for imported milk products in the short term and to develop dairy units throughout the country in the long term to provide milk for the rural population.

The commercial dairy farms are mainly run by the parastatal organisations including Tanzania Dairy Farming Company Limited (DAFCO), Tanzania Sisal Corporation (TSCO), National Agricultural and Food Corporation (NAFCO) and co-operative unions. The projected milk production targets of 10 m litres per annum have not been realized due to a lot of problems including inadequate herd size on various farms. This implies that imported milk products have continued to increase to meet the market demand for milk.

The traditional sector which produces about 365 m litres of milk per annum plays an important role in supplying milk to the rural population. Strategies to develop this sector should therefore focus on up-grading and selection coupled with improved management and feeding.

The smallholder dairy farmers increase the supply of milk in rural areas and nearby urban areas. They are very efficient when compared with commercial producers. This system is being encouraged by ensuring that dairy heifers are available for them and providing essential services such as artificial insemination.

Having discussed briefly various herds of the livestock sector and the role they have in the economy and the nutrition of the people in the country, a trend which may resemble that in some of your countries, I have to point out that the contributions made by the sector have been due to efforts and progress made in the control of animal diseases, and to some extent to the genetic improvement of local breeds of livestock.

Mr. Chairman, the livestock sector would have been in a position to contribute more to the economy and nutrition of the people, if sociological, economic and animal nutrition constraints were solved. PANESA is therefore charged with the responsibility of generating scientific knowledge in the short and long term to utilise the range resources for the benefit of current and future generations. The knowledge sought should be able to allow for multiple range resource use for sustained range productivity. Part of this task has been initiated by the Range Management and Tsetse Control Section in my Ministry. It is hoped that combined efforts of this section and those of the Pasture Research Institute to be established at Kilosa and sister pasture research institutes in PANESA member countries will realise findings to exploit range resource. I wish you the best of success in this workshop.

SESSION I: AFRICAN FORAGE PLANT GENETIC RESOURCES

SOME THOUGHTS ON THE COLLECTION, INTRODUCTION AND EVALUATION OF PASTURE LEGUMES IN ZIMBABWE

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Abstract

Results of screening trials with pasture legumes in Zimbabwe are reviewed. The Stylosanthes *spp. proved especially suitable for reinforcement of native grazing on sandy soils because of their ability to establish under adverse conditions and to persist and spread under grazing. On heavier soils or on ploughed land a wider range of legumes showed promise, with* Desmodium *spp. outstanding in the higher rainfall areas. On an infertile sand in a lower rainfall region only* Macrotyloma axillare *cv Archer and* Macroptilium atropurpureum *cv Siratro were productive.*

The importance of defining the likely role of legumes in local livestock production systems and relating the evaluation procedure to this use is stressed. This is illustrated in the trials described by an increasing trend towards including grazing in the evaluation process.

INTRODUCTION

The introduction and evaluation of potential pasture grasses and legumes occupy a large proportion of the time of most pasture research teams and it is obvious that this is a field in which the PANESA network will be deeply involved. The pasture section at Grasslands Research Station has, since the mid-1950's but particularly since 1970, been involved in the introduction, evaluation and incorporation into farming systems of forage and pasture legumes. During this period the section made many mistakes, learnt many lessons and changed its ideas and methods several times. In the hope that these experiences may be of interest to other workers in this field in Eastern and southern Africa, an attempt has been made to summarise the experiences in this paper. Most of the results presented and discussed here have been published elsewhere, and for that reason the methods employed are not described in detail. Emphasis is placed on comparisons of several species or strains under common conditions rather than on comparisons of techniques involving only one or a few strains.

METHODOLOGY

Introduction Nursery

The procedures used in the introduction nursery (Clatworthy, 1975) are similar to those used in almost all introduction nurseries worldwide. Seeds are inoculated with Rhizobium strains known or thought likely to be effective on that species and are sown in a single row on fertilized soil. The nursery beds may be watered to ensure establishment but not thereafter. Records are kept of the habit, vigour, persistence, flowering date and flower characteristics, seed set, disease and pest attack and other features of interest for each introduction. The beds are kept weed-free for the first two seasons but not after that. Only in exceptional cases are plants harvested from the nursery.

Seed is reaped from all lines initially to ensure a reserve of seed, but once this has been achieved, more seed is bulked only from those lines showing promise.

Where feasible, cattle are allowed access to the introduction nursery from the fourth year onwards so that the acceptability of the legumes to stock can be observed. The introduction nursery is intended only as a very coarse screen to eliminate those plants which are obviously unsuited to conditions in the area. A large proportion of the introductions will warrant further testing to determine their agricultural potential, and it is with the techniques which should be used for this testing that this paper is primarily concerned.

The introduction nursery is on Grasslands Research Station (18° 11'S, 31° 30'E, 1630 m.a.s.l., 873 mm a.a.r., granite-derived sandy loam soils). Other trials to be discussed were carried out on Henderson Research Station (17° 35'S, 30° 58'E, 1290 m.a.s.l., 869 mm a.a.r., mainly silty clay loam soils derived from metasediments) and Makoholi Experiment Station (19° 50'S, 30° 47'E, 1200 m.a.s.l., 650 mm a.a.r., granite derived sandy soils). In all cases fertilizers were applied, but, to save space, details of fertilizer treatments are not given here.

Establishment

Included in this section on establishment are trials in which seedling density or establishment percentages were determined, even though the work was primarily intended for some other purpose. For this reason the same experiment may be discussed under two or more headings.

Veld Reinforcement

With the anticipation that the main benefit from the use of pasture legumes would come from their introduction into large areas of native grazing or veld, early trials therefore concentrated on this aspect of the work.

Experiment 1. (Clatworthy and Thomas, 1972). Seeded at Grasslands in December, 1964 on native grassland on an infertile coarse sand.

Treatments comprised:

unsprayed or sprayed with 1.4 l/ha of Gramoxone
disced to 25 or 100 mm depth
left bare or mulched with 500 kg/ha of hay after seeding
Desmodium intortum, Lotononis bainesii, L. listii, Stylosanthes guianensis and *Trifolium semipilosum.*

The seed was broadcast on the soil surface and was not covered, except by mulch on the appropriate plots. Surviving plants were counted on three occasions in the ten months following seeding.

Experiment 2. (Clatworthy, 1980). At Grasslands and Henderson, mainly to test the effects of grazing management on the persistence of twelve legume strains seeded into disced veld. The legume seeds were broadcast on the soil surface in December, 1970 and plants were counted in February and July and early in the next rains.

Experiment 7. Seeds of 13 strains of *Stylosanthes* spp. and of Siratro were sown on fertilised disced strips in native grassland at Chibero Agricultural College (18° 06'S, 30° 40'E, 1335 m.a.s.l., 805 mm a.a.r., clay soil derived from dolerite) and at Matopos Research Station (20° 24'S, 28° 28'E, 1340 m.a.s.l., 585 mm a.a.r., coarse sand derived from granite) in December, 1981. Seeding rates were calculated to allow 400 viable seeds of the *Stylosanthes* spp. or 150 of Siratro. The seed was dropped in a line on the soil surface and then lightly raked. The paddocks concerned were included in the normal grazing rotations and seedlings were counted at the end of the establishment season.

Sown Pastures

Quite early in the work it became obvious that farmers were mainly sowing pasture legumes on ploughed land, usually after a period of cropping, and accordingly, increased emphasis was placed on this aspect.

Experiment 3a. (Grant, 1976). Approximately 250 viable seeds of *Desmodium intortum*. Oxley fine-stem stylo and Siratro were sown on three dates in the 1973-74 season on the surface or in drills 10 mm deep on soil which had been fumigated with methyl bromide.

Experiment 3b. (Grant, 1976). The same three legumes were sown in 1974-75 late in the dry season, just before the rains or after rain had fallen and the first crop of weeds been destroyed. Half the area was fumigated with methyl bromide, all seeds were sown in drills 10 mm deep and half the plots were mulched with broken maize cobs after seeding. In both of these experiments seedings were counted frequently, with the final count during the following rains.

Experiment 4. (Clatworthy, in press,a). Twelve strains of *Stylosanthes* spp. covering *S. fruticosa, S. guianensis, S. humilis, S. scabra, S. subsericea* and *S. viscosa* were sown on ploughed and disced land at Grasslands and Henderson (1973-74) and at Makoholi (1974-75) at a constant seed rate of 10.7 kg/ha. Five strains were common to all three sites; others were chosen on the basis of likely adaptation to the particular site. The seed was broadcast and lightly covered and seedlings were counted approximately two months after sowing.

Experiment 5. (Clatworthy, in press,b). Twelve strains of legumes which it was thought might prove suitable for use in ley pastures were sown on ploughed and disced land at Grasslands and Henderson (1973-74) and at Makoholi (1974-75). Six strains were common to all sites and the others were chosen on the basis of their likely adaptation to that area. Seeds were sown at rates applicable to commercial use in shallow drills 0.5 m apart and were kept weed-free during the season of establishment. Seedlings were counted at Grasslands and Makoholi early in the first dry season after sowing.

Evaluation Trials

Included in this section are trials in which the comparative performance of a number of legume strains, in terms of yield, persistence, acceptability to stock or other desirable features, is determined over several years.

Undercutting Only

Experiment 4. (Clatworthy, in press,a). Twelve strains of *Stylosanthes* spp. were sown at Grasslands, Henderson and Makoholi. Yields were determined by cutting to a height of 75 mm once or twice per season.

Cutting Trials Involving Grazing

Combined with cutting

Experiment 5. (Clatworthy, in press,b). Twelve legume strains with potential for use in ley pastures were sown at Grasslands, Henderson and Makoholi. Yields were determined by harvesting quadrats from each plot twice or three times per season. After each sampling a group of cattle were put into the experiment and remained there until the most selected legumes had been grazed to approximately the sampling height. After the cattle had been removed, the apparent acceptability of each legume was scored and the whole experiment was then slashed to sampling height.

Alternating with cutting

Experiment 6. Thirty lines of *Neonotonia wightii* and four of perennial *Glycine* spp., with Silverleaf desmodium and Siratro as controls, were sown in replicated rows at Henderson. At the end of the establishment season the rows were sampled for measurement of dry-matter yield and of seed production. In the following season half of each row was harvested four times, and half once, and yields were again measured. The trial area was then fenced and grazed hard by cattle for two seasons; grazing was sufficiently severe that topping after grazing was not necessary. In the fifth season the plants were again harvested to determine how well they had survived the grazing.

Grazing Trials

Experiment 2. (Clatworthy, 1980). Twelve legumes were sown in replicated blocks on disced veld at Grasslands and at Henderson. Each trial was fenced into six paddocks which were grazed at 250 and 50 cdh in the growing season only, in the dry season only or year-round using a simulated rotational grazing system. The percentage frequency of occurrence of the legumes, and of other species, was determined early in the dry season each year. The trial at Henderson was burnt by a very hot escaped fire in July,

1976. In the late dry season of 1978 the herbage in both trials was mown and removed and in February, 1979 quadrats were harvested from each plot for yield determination.

Experiment 7. Plants of 13 *Stylosanthes* spp. and of Siratro which had been sown on disced strips through grazed veld were counted annually in the late growing season in order to measure their persistence and spread. Notes were also made of such features as plant vigour, degree of grazing and any obvious signs of disease or pest attack.

RESULTS

Establishment

Veld Reinforcement

Experiment 1. The seed was sown onto moist soil, but seeding was followed by a period of hot, dry weather. Both the herbicide spray and deep discing improved establishment, but the effect was not additive. Mulching had little effect although it caused an initial increase in seedling numbers on the shallowly-disced treatment. Table 1 shows that the legumes fell into three distinct categories: *Stylosanthes guianensis* had good initial establishment and good survival; *Lotononis bainesii* and *L. listii* had poor initial establishment but excellent survival, while *Desmodium intortum* and *Trifolium semipilosum* had moderate to poor initial establishment and poor survival. As a result of this experiment, most of the establishment trials done between 1965 and 1970 were done with *S. guianensis* only.

Table 1. Total surviving plants of five legumes seeded onto disced sandveld at Grasslands Research Station, on 24 December, 1964.

	Date of count		
	Feb 1965	May 1965	Oct 1965
Desmodium intortum	37	13	5
Lotononis bainesii	32	32	34
L. listii	10	11	9
Stylosanthes guianensis	379	305	280
Trifolium semipilosum	66	26	12

Experiment 2. The twelve legumes were sown on disced veld in December, 1970. At Grasslands seeding was followed by a hot, dry period, but the weather at Henderson was considerably more favourable for establishment. Stands of all legumes were therefore denser at Henderson. At Grasslands the *Stylosanthes* spp. had the largest establishment percentages, especially at the count after the dry season. At Henderson the differences in establishment percentages were much smaller and all legumes except the two *Lotononis* spp. produced good stands.

Table 2. Establishment as percentage of viable seed of 12 legumes sown on disced veld at Grasslands and Henderson Research Stations in December, 1970.

	.......Grasslands......			.......Henderson.......		
Legumes	Feb'71	July'71	Nov'71	Feb'71	July'71	Feb'72
D. intortum	6.43	0.26	0.04	27.92	15.07	7.78
D. sandwicense	10.78	0.45	0.09	39.89	25.81	16.72
D. uncinatum	14.70	0.20	0.03	61.46	43.65	33.91
L. bainesii	0.10	0.00	0.01	0.58	0.39	0.39
L. listii	0.72	0.01	0.01	1.92	0.80	0.61
M. atropurpureum	25.70	6.40	6.53	34.18	28.15	23.37
N. wightii	46.46	5.07	3.58	96.13	76.13	50.08
S. fruticosa	14.25	15.55	15.00	18.82	15.99	15.76
S. guianensis Scho	30.56	24.55	12.13	45.84	44.32	43.72
S. guianensis Oxley	30.61	30.60	20.45	24.36	19.41	16.30
S. guianensis erect	55.90	53.43	18.78	95.39	88.18	72.69
S. humilis	17.90	16.66	9.96	17.89	14.39	15.78

Sown Pastures

Experiment 3a. The three legumes were sown on three dates, either in shallow drills or on the surface of moist soil which had been fumigated with methyl bromide. The numbers of seedlings which had emerged three weeks after seeding are shown in Table 3. There was little difference in stand densities between the first two sowings, but the third date produced the greatest emergence. Sowing in drills had a marked beneficial effect, which was least with Siratro and greatest with *Desmodium intortum*.

Table 3. Effects of date and of depth of sowing on the numbers of seedlings of three pasture legumes three weeks after seeding.

Date sown	Pasture legume	Surface sown	Drilled 10 mm deep
	Oxley stylo	20	82
1 Nov'73	Siratro	52	85
	Desmodium intortum	6	131
	Mean	26	99
	Oxley stylo	8	90
23 Nov'73	Siratro	56	104
	Desmodium intortum	9	106
	Mean	24	100
	Oxley stylo	26	161
4 Jan'74	Siratro	84	161
	Desmodium intortum	24	208
	Mean	4	177

Experiment 3b. The same three legumes were sown on three dates in shallow drills on soil which had or had not been fumigated with methyl bromide and which were or were not covered with a mulch after sowing. Table 4 shows the number of seedlings which established in the various treatments. Mulching proved beneficial, and the effect was consistent for the three legumes. Soil fumigation also increased establishment and the effect was most marked with *Desmodium intortum*, which virtually failed on the unfumigated plots.

Table 4. Effects of soil fumigation with methyl bromide and of mulching with 10 t/ha of broken maize cob on mean seedling numbers of three pasture legumes.

	Unmulched	Mulched	
Not fumigated			
Oxley stylo	38	62	
Siratro	35	43	
Desmodium intortum	3	9	
Mean	25	38	32
Fumigated			
Oxley stylo	64	72	
Siratro	42	56	
Desmodium intortum	45	68	
Mean	50	65	58

The results of these two experiments confirm those already presented for the veld reinforcement trials which showed that *Desmodium intortum* is considerably more susceptible to stress during seedling establishment than are Siratro or Oxley fine-stem stylo.

Experiment 4. Twelve strains of *Stylosanthes* spp. (but not the same 12 at each site) were sown on ploughed and disced land at Grasslands, Henderson and Makoholi. Seedlings were counted approximately two months after sowing, and at Grasslands and Henderson differences between the strains in seedling density were highly significant. Seedling density was not affected by seed size but was positively correlated with germination percentage.

When establishment was expressed as percentage of viable seeds sown, there were significant differences between the strains at all three sites. There was a consistent negative correlation between establishment percentage and the germination percentage of the seed sample. This must have resulted from the germination in the field of some hard seed which did not germinate in the incubator. Seed size had no effect on establishment percentage.

Experiment 5. Twelve strains of legumes with possible potential for use in ley pastures were sown in shallow drills on ploughed and disced land at Grasslands, Henderson and Makoholi. At Grasslands and Makoholi seedlings were counted approximately six months after seeding, and at both sites differences in seedling density were highly significant. Seed size had no effect on seedling density (showing that the different seeding rates were effective in reducing variation), but seedling density was again positively correlated with germination percentage. Establishment percentage of viable seeds sown was negatively correlated with the number of seeds per gram, showing that larger seeds had a greater probability of successful establishment.

These counts were done in June, by which time in Experiment 2 the *Stylosanthes* spp. had shown superior survival at Grasslands over the other genera under the rigorous conditions of veld reinforcement in a season of below-average rainfall. This advantage was not demonstrated in the present trial in the easier conditions on ploughed land on which weeds were controlled and in a very wet season.

Evaluation Trials

Undercutting Only

Experiment 4. Twelve strains of *Stylosanthes* spp. covering a total of seven species, with five strains common to all sites, were sown at Grasslands, Henderson and Makoholi and were harvested once or twice per season for a minimum of three years. The results presented in Table 5 show that in the season after sowing, maximum herbage yields of stylo at all sites were close to or greater than 5 t/ha of dry matter. Strains of *Stylosanthes guianensis* were the highest-yielding at all sites, the solitary exception being in the establishment season at Makoholi where greater yields were produced by the annual species *S. humilis* and *S. subsericea*. But the persistence of the stylos was poor, and few lines were productive by the fourth year of the trial. Even strains such as Oxley fine-stem stylo, which was known to persist well under grazing at Grasslands, had declined markedly by the fourth harvest season. From observations in grazed plots, there appeared to be a rough correspondence between the persistence of the strains under cutting and under grazing. Nonetheless the results provided only very poor indication of the possible value of the *Stylosanthes* spp. under grazing conditions, especially for the annual species for which the cutting treatments effectively prevented seeding and regeneration.

Cutting Trials Involving Grazing

a) Combined with cutting

Experiment 5. Twelve strains of legumes of potential value in ley pastures were sown in shallow drills on ploughed and disced land and were kept reasonably weed-free in the establishment season. From the second season onwards, yields were determined by harvesting quadrats from each plot. After sampling, cattle grazed the trial until the most palatable legumes had been grazed to approximately sampling height. The cattle were then removed, the extent to which the different legumes had been grazed was noted and the trial mown.

Table 5. Dry-matter yields (g/sq.m) of Stylosanthes strains at three sites in Zimbabwe.

G. No	Grasslands				Henderson			Makoholi			
	'73-4	'74-5	'75-6	'76-7	'74-5	'75-6	'76-7	'74-5	'75-6	'76-7	'77-8
S. fruticosa											
781								5.3	104.7	25.7	107.0
1142	1.0	1.7	2.3	0							
S. guianensis											
4	14.0	145.3	105.0	0	495.7	471.0	201.3	66.7	351.7	38.7	7.7
335	15.3	215.3	119.3	17.7							
681	87.3	520.7	136.3	0	383.0	112.0	97.7	92.3	176.3	15.0	0
731	12.0	300.7	176.3	79.3	484.7	339.3	282.3	38.7	161.0	43.3	101.0
1053	3.0	52.0	13.7	0							
1056	17.3	400.3	337.0	30.0							
1101	17.3	154.0	68.7	18.7				109.7	624.7	71.3	1.0
1103	50.3	438.7	185.7	14.7	398.3	88.3	165.0	150.0	450.7	33.7	4.3
1138	35.7	413.0	235.7	3.3	205.0	412.7	234.7	154.3	465.3	27.7	3.7
1141					358.0	16.3	16.7				
S. hamata											
1106					116.4	81.7	64.3				
S. humilis											
1076					124.4	96.7	28.7				
1077					153.6	62.0	7.3	238.0	28.3	0	1.3
S. subsericea											
1143	4.0	86.7	60.3	4.0							
S. viscosa											
1119	1.0	3.0	4.7	0	116.0	32.3	53.7	171.0	39.0	3.0	3.3
1179								61.0	5.3	0	0.3
S. viscosa											
1146	0.3	4.0	13.3	3.0				24.7	108.3	42.7	15.0

G. No = Plant introduction number

At both Grasslands and Henderson *Desmodium intortum* was the outstanding legume, with an average annual yield of more than 8 t/ha at Grasslands and 6 t/ha at Henderson. The other two *Desmodium* strains were also highly productive, as was Archer but Archer proved considerably less acceptable to cattle than the other legumes.

At Henderson, fire burnt the whole trial after the second sampling season and affected all the legumes, although none was completely eliminated. Yields in the final season were very low compared with previous years, perhaps because the poorly drained site became waterlogged in a year of exceptionally heavy rain. Work in Australia has shown that few of the pasture legumes can tolerate prolonged waterlogging (McIvor, 1976).

At Makoholi only Archer (1.7 t/ha) and Siratro (1.6 t/ha) were productive. Results at this site were very different from those at Grasslands and Henderson. Makoholi would normally be regarded as having submarginal rainfall for sown pastures but this trial coincided with a period of above-average rainfall, and a more likely reason for the failure of the legumes would be the inherently low soil fertility.

The effect of grazing in these trials was very small as the plots were topped immediately after grazing, and for all practical purposes these could be regarded as pure cutting trials. In ley pastures the main selection criterion is to produce the maximum yield of herbage over a relatively short life of the pasture, and that can be measured sufficiently accurately in cutting trials. The main advantage from the use of animals in this trial was that it demonstrated clearly the very low acceptability of Archer.

(b) Alternating with cutting

Experiment 6. Thirty lines of *Neonotonia wightii*, four of perennial *Glycine* spp. and Siratro and Silverleaf desmodium were sown in replicated rows at Henderson. When sampled at the end of the establishment season, the highest yielding legumes were Silverleaf desmodium and three strains of *N. wightii* cv Cooper, CPI 25702 (from which Cooper was selected) and an introduction from Angola which was almost certainly also Cooper. In the second season, half of each row was harvested four times and the other half at the end of the growing season only. The same four legumes were again the highest-yielding. The trial was then fenced and grazed by cattle for two seasons. In either season there was a detectable difference in the acceptability of the various strains, and in both seasons grazing was sufficiently severe that slashing was unnecessary.

In the final year the legumes were harvested twice to measure their persistence after the period of grazing. At this harvest the three Cooper lines and Silverleaf desmodium produced yields below average, and the three highest-yielding lines were all *Neonotonia wightii* strains of Zimbabwean origin. These were very similar in their visual characteristics and in flowering time, and it is intended to combine them and release the mixture as a pasture cultivar.

This trial illustrates the need to continue screening for a reasonable period before conclusions are reached. It is tempting to ascribe the failure of the Cooper lines to a lesser ability to withstand grazing, but, in the absence of a cutting-only control, this is not justified and may have been merely an effect of time. At least, though, we can be confident that our selected lines will persist for the normal life of a pasture, even under severe grazing pressure.

Grazing Trials

Experiment 2. Twelve legumes were sown in six replicated blocks on disced land at Grasslands and Henderson. Each legume was sown in two plots in each block. The blocks were fenced separately and were grazed at two stocking rates in the dry season only, the wet season only, and year-round using a simulated rotational grazing system.

At Grasslands only the five stylo strains and Siratro established in reasonable density, and of these Oxley fine-stem stylo proved outstanding. It persisted well and spread into plots in which it had not been sown and appeared particularly favoured by grazing during the growing season.

At Henderson a much wider range of legumes established and persisted throughout the trial. Schofield stylo initially was outstanding but it appeared short-lived and Silverleaf desmodium was the most impressive legume in the middle stages. The fire in 1976 affected all the legumes, although none was completely eliminated, but *Lotononis bainesii* and *L. listii* recovered rapidly and were the most prominent legumes at the end of the trial. Silverleaf desmodium was especially favoured by grazing in the dry season only while the *Lotononis* spp. grew best in plots which were grazed in the growing season.

The large differences between the results from the two sites in this trial emphasise the need for multi-site testing covering a range of soil and climatic conditions if results are to have a widespread applicability. The results also emphasise the need for the long continuation of trials and also for recurrent natural hazards, such as fire, to be incorporated in the design. The season of grazing treatments proved useful; doubling the stocking rate did not. This type of trial is of value in determining which strains justify large-scale testing in animal production experiments.

Experiment 7. Seeds of a range of *Stylosanthes* spp. and of Siratro were sown on disced strips in veld and grazed in normal farm practice. Surviving plants were counted at intervals, normally in the late growing season of each year. The results are a combination of the ability of each strain to establish and to persist. At nearly all sites the greatest number of seedlings were from *S. guianensis* strains, but *S. scabra* proved hardier and had a greater percentage survival. At Grasslands in 1984 there was evidence of increases in stand density of *S. fruticosa*, *S. viscosa* and all *S. scabra* lines, and this trend continued into 1986. All of the stylos were grazed and even the notoriously-unpalatable *S. viscosa* appeared to be well eaten by the late dry season.

Table 6. Dry-matter yields (g/sq.m) of potential legumes for ley pastures at three sites in Zimbabwe.

G. No	asslands				Henderson				Makoholi			
	'74-5	'75-6	'76-7	'77-8	'74-5	'75-6	'76-7	'77-8	'75-6	'76-7	'77-8	'78-9
Alysicarpus rugosus												
707					193.0	711.7	379.3	110.0				
Cassia rotundifolia												
1126									79.0	14.3	78.3	10.3
Clitoria ternatea												
705									0.3	0	0	0
Desmodium intortum												
369	657.3	784.7	991.3	797.7	642.7	799.3	595.7	356.7				
D. sandwicense												
701	438.0	587.7	722.0	532.7	634.7	715.0	185.3	1.0	54.3	5.3	0	0.3
D. uncinatum Silverleaf												
373	346.0	567.3	525.7	614.7	530.7	778.0	371.3	124.3	59,0	3.0	6.3	0.7
Galactia striata												
1108	72.3	23.7	60.3	53.7	157.0	192.0	168.3	33.0				
Lotononis bainesii												
729	379.7	15.7	97.7	36.3	-	204.0	212.0	52.0	33.3	1.0	4.3	0.3
Macroptilium atropurpureum												
699	37.7	51.7	58.7	67.7	247.3	433.3	245.0	102.3	230.7	102.3	174.7	115.7

Table 6 (cont'd).

G. No	Grasslands				Henderson				Makoholi			
	'74-5	'75-6	'76-7	'77-8	'74-5	'75-6	'76-7	'77-8	'75-6	'76-7	'77-8	78-9
Macrotyloma axillare cv Archer												
1307	490.0	402.0	254.3	145.3	344.7	461.7	347.3	57.0	293.0	129.3	169.7	95.7
Neonotonia wighitii cv. Cooper												
937					275.0	475.0	187.0	19.3	19.3	3.3	1.0	0
1027	186.3	272.0	191.3	316.3								
Stylosanthes fruticosa												
781									37.0	6.3	37.7	2.0
S. guianensis (4=cv Schofield, 731=cv Oxley)												
4	10.3	3.0	2.7	0	132.7	408.7	20.7	40.3				
731	159.7	152.0	136.0	152.0					91.0	20.3	77.0	7.7
S. humilis												
1076									1.3	0	0.7	0
Teramnus labialis												
981	87.7	137.7	182.3	197.0								
Trifolium semipilosum												
	91.7	42.3	57.3	50.3								
Vigna vexillata												
59									2.7	0	0	1.0
1111					199.0	146.3	200.3	29.3				

G. No = Plant introduction number.

Yields of Siratro and Archer at Makoholi in 1976/77 are both underestimated by unknown amounts.

DISCUSSION

In Zimbabwe, as in most parts of the tropical and subtropical world, the main legumes used in pastures are of Central or South American origin. Few locally collected legumes were included in the trials described here: of these, *Stylosanthes fruticosa* could prove of importance in the medium-rainfall parts of Zimbabwe and *Neonotonia wightii* on heavier soils in the better-watered areas. Indigenous strains of *Alysicarpus rugosus, Lotononis listii, Macrotyloma axillare* and *Teramnus labialis* (all of which performed well in one or more of the trials described in this paper) also occur in Zimbabwe. However, diseases and pests have posed problems with indigenous strains, especially when grown in pure stands for seed production and may limit their usefulness compared with introductions.

For national institutions with limited resources the most logical first stage is to introduce strains of pasture plants of proven or suggested value under similar conditions elsewhere and to test those. Inevitably research and extension workers and farmers will collect, on a casual basis, seeds of grasses or legumes which catch their attention, usually because of productivity, growth habit or acceptability to stock. This is healthy and can pay big dividends, but it is doubtful if a heavy commitment to pasture plant collection is a wise use of national resources ard it is disturbing that emphasis has been given to plant collection at the IDRC/PANESA/ILCA training course in "Forage Plant Introduction and Evaluation" in October, 1986.

There are excellent chapters on pasture plant evaluation in several books (Shaw *et al.*, 1976; 't Mannetje *et al.*, 1976; Cameron and McIvor, 1980; Jones and Walker, 1983). The stages which have evolved in this paper largely echo those which are outlined by those authors, particularly in regard to the need to consider the likely use of the plant from an early stage in the evaluation process. This is especially relevant in Africa, with its multiplicity of livestock production systems, ranging from intensive cut-and-carry milk production to extensive and largely uncontrolled grazing of rangeland. For cut-and-carry systems the yield of the forage is the most important criterion, and this can be adequately assessed in simple cutting trials, ideally combined with some assessment of the nutritional value of the herbage. For rangeland improvement, the criteria of success depend more on persistence and spread under grazing, which can really only be measured *in situ*. The likely use of the forage plants within the local farming systems will need to be borne in mind in planning the evaluation trials within the PANESA network. Except in the most basic stage, that of the observation nursery, the type of accession chosen for testing, and the form of treatments imposed, should be defined to a great extent by the role the plant is to play in the livestock system. In many cases in Africa the farming systems, the roles of livestock within them and the potential benefits which can be derived by the growing of forage plants, are not yet clearly defined and this makes the task of the researcher dealing with small-scale farming systems more difficult than that of the worker with well-defined commercial livestock operations. The authors believe, though, it should be possible to postulate suitable roles and types of forage plants for each area and to derive likely "short lists" of promising lines for more detailed evaluation. They query whether time will be best spent testing a complete and common spectrum of pasture grasses and legumes under the full range of conditions covered by the PANESA region as that seems a complete negation of the region's collective experience built up over so many years.

A major deficiency of the experiments on ploughed land described in this paper is that in all cases the legumes were sown in pure stands. Except when intended as protein banks, either grazed *in situ* or cut and conserved, there are considerable advantages to combining a grass with the legume, and the selection of productive and compatible mixtures is a complex and demanding task. Again, though, a great deal can be learnt from experience under similar conditions elsewhere. In particular we in PANESA need to study the methods used, and the lessons learnt, by the extensive and growing Tropical Pastures Evaluation Network (RIEPT) in South America and the neighbouring regions. Unfortunately the manuals of procedure produced by RIEPT are all in Spanish, which limits their usefulness in Africa, but it would be of great value if a senior member of that network (and also possibly of the South East Asia/Pacific Forage Research and Development Program) attend future PANESA workshops.

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REVIEW OF RANGE AND PASTURE PLANTS IN BOTSWANA

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Abstract

Botswana vegetation is arbitrarily classified into the hardveld, sandveld and Okavango deltaveld. In spite of this arbitrary subdivision some species are specific to a particular vegetation type. The species vary generally in their nutritive value; woody plants (12.63% CP; 47.60% DMD) are relatively higher than grasses (5.49% CP and 40.61% DMD). Within a species there is a seasonal variation in nutritive value. For instance Panicum maximum *is higher in the wet season (10.4% CP; 60% DMD) than in the dry season (8.7% CP; 36% DMD).*

Agronomic trials were initiated in the 1970/71 season, but these were discontinued and resumed in 1976 with a broader objective of screening a wide range of germplasm suitable for pasture production. These trials were terminated in 1982 only to resume in 1986. It was found that Macroptilium atropurpureum, Leucaena leucocephala, Lablab purpureus *and* Cenchrus ciliaris *were the most promising species. Current collaborative trials with ICRISAT and ILCA involve the screening of varieties of millet and sorghum, some forage grasses and legumes. In future focus will be directed to indigenous species as well.*

Where fertilizer application tests to range were conducted a yield increase was recorded, but economic feasibility indicated that it would be of no practical value in the immediate future.

INTRODUCTION

Botswana, extending from 18°S to 27°S and 20°E and 29°E is situated on the Southern African Plateau with a mean altitude of 1,000 m.a.s.l. It covers 582,000 sq. km with marked topographical features mainly in the east on the hardveld, where the soil is capable of supporting arable agriculture. The hardveld is a narrow strip covering about 20% of the country. In the northwest is the Okavango Delta. The rest of the country is covered by the Kalahari sand.

Rainfall averages 450 mm per annum. There is great variation in amount and distribution from location to location and from year to year. The rainfall is highest in the northeast at 650-700 mm decreasing to a minimum of 100-200 mm in the southwest. Rainfall occurs in October-April and over 90% of rain occurs in November to March. Beginning and end of rains are equally unreliable. Early planting might suffer from drought, or late planting may never get established.

Evaporation often exceeds 2 m per annum, and humidity is low. There is quite a large difference between morning humidity and afternoon humidity. Temperatures reach 31°C in December and January, and daily variation averages 13°C. Frost is common in winter in the south.

Livestock form an important industry accounting for 20% of the foreign exchange economy. In 1982 the cattle population was 3 million; this figure dropped to 2.5 million by 1986 due to drought. However, the cattle population has been increasing as drought years are often followed by good rain years. Cattle density is high in the hardveld; however, in the past few years the Kalahari has been intruded upon by large numbers due to opening of more ground waters. The Okavango delta is still lightly used due to the trypanosomiasis-transmitting tsetse fly, and in other areas range degradation is widespread, especially around watering points.

There are a number of reports that categorise the vegetation of Botswana, notably those by Wear and Yalala (1971), DVH (1979) and Timberlake (1980). There are three major vegetation types in Botswana. The first of these, the hardveld type, is characterised by grasses *Panicum coloratum, Themeda triandra Cenchrus ciliaris, Enneapogon cenchroides, Eragrostis superba, Chloris gayana, Heteropogon contortus, Brachiaria deflexa* and *Bothriochloa insculpta*. It is associated with such woody plants as *Acacia karroo, Albizzia anthelmintica, Balanites aegyptiaca, Colophospermum mopane, Combretum apiculatum, Grewia bicolor, G. flavescens, G. monticola, Lonchocarpus capassa and Terminalia prunioides*. The second type which is specific to the Kalahari sandveld consists of grasses, *Eragrostis pallens, Stipagrostis uniplumis, Anthephora pubescens, Schmidtia pappophoreides* and *Megaloprotachne albescens* associated with woody plants *Grewia avellana, G. retinervis, Lonchocarpus nelsii* and *Terminalia sericea*.

The last type is specific to the Okavango Delta, and it includes the grasses *Phragmites communis, Dichanthium papillusum, Panicum repens, Andropogon encomus, Echinochloa pyramidelis, Imperata cylindrica*, and woody plants *Ficus verruculosa* and *Hyphaene crinata*.

The purpose of this paper is to discuss the forage values and review some of these forage species that have been tried for pasture in Botswana.

RANGE AGRONOMY METHODOLOGY

The history of range agronomy in Botswana goes back to 1970 for only a short period (FAO, 1971). The work resumed in 1976 and continued up to 1982 when there was a cessation of fodder plant screening from 1983 to 1985. Finally the work resumed again in 1986. The range agronomy section has tested promising species into farming systems programmes with local farmers. These were primarily the introduced species *Stylosanthes humilis, Neonotonia wightii, Macroptilium atropurpureum, Stylosanthes guianensis* and *Rhynchosia sublobata*. It has also determined the nutritive value (CP% and DMD%) of a variety of range grass and woody plants in some vegetation types.

At some stage in the screening programme (1976/77), the increase in rangeland yield by applying fertilizer was tested at Morapedi in an *Acacia erioloba* tree savanna on the Kalahari sandveld. A combination of nitrogen and phosphorus was applied in the form of urea and superphosphate respectively. Urea was applied at four levels (0, 50, 100, 150 kg/ha) and superphosphate at two levels (0, 33.2 kg/ha). The fertilizer work was extended to Marale in 1979 with a vegetation cover composed of *Acacia nigrescens/Combretum apiculatum* tree savanna in the hardveld. Three fertilizers, nitrogen, phosphorus and potassium in the form of ammonium sulphate, superphosphate and potassium chloride respectively were applied in combinations of two. Levels of ammonium sulphate were 0, 250, 500 and 750 kg/ha; those for superphosphate were 0, 400 and 800 kg/ha, while those for potassium chloride were 0 and 50 kg/ha.

RESULTS

The nutritive values in terms of crude protein and dry-matter digestibility of some range grasses in the hardveld and the Kalahari sandveld are shown in Tables 1 and 2 respectively. The hardveld grasses are generally of a higher nutritive value than those of the Kalahari sandveld. These data are means over a 29-month period. However, within this period it was observed that protein values were quite high during the wet season, resulting in good livestock performance on them. During the dry seasons the range grasses were characterised by low protein values, lower than maintenance requirement, and thus animals lost weight.

Table 1. Crude protein (CP) and dry-matter digestibility (DMD) of some range grasses in the hardveld, values in %.

Species	CP	DMD	Source
Aristida congesta	4.9	37	APRU, 1977
Panicum maximum	8.8	49	"
Eragrostis rigidior	3.6	33	"
Enneapogon cenchroides	5.3	40	"
Heteropogon contortus	4.5	39	"
Brachiaria nigropedata	6.8	43	"
Urochloa trichopus	8.0	46	"
Bothriochloa insculpta	6.4	39	"
Digitaria eriantha	6.3	47	"
Means	6.1	41	

Note: APRU 1977 values are averages of 29 months.

Tables 3 and 4 show the nutritive values of some wood range plants in the hardveld and the Kalahari sandveld, respectively. There are no major discernible differences between the nutritive values of hardveld and sandveld species. However, the woody species are generally higher in nutritive value than grasses in both vegetation types. This means that browsing is an important supplementation feed resource for these animals on range.

Results of the exotic plants screening work indicated that *Stylosanthes* spp. and *Macroptilium atropurpureum* made good

Table 2. Crude protein (CP) and dry-matter digestibility (DMD) of some range grasses in the Kalahari sandveld, values in %.

Species	CP	DMD	Source
Aristida congesta	4.4	37	APRU, 1977
Eragrostis lehmanniana	4.0	33	"
Eragrostis pallens	3.[illegible]	32	"
Stipagrostis uniplumis	4.2	32	"
Anthephora pubescens	6.0	49	"
Schmidtia pappophoroides	5.5	48	"
Brachiaria nigropedata	6.5	42	"
Pogonathria squarrossa	3.9	38	"
Digitaria eriantha	5.8	47	"
Means	4.9	39	

Note: APRU 1977 values are averages of 29 months.

Table 3. Crude protein (CP) and dry-matter digestibility (DMD) of some range woody plant leaves in the hardveld, values in %.

Species	CP	DMD	Source
Acacia tortilis	14.6	43	APRU, 1985
Acacia karroo	12.8	40	"
Balanites aegyptiaca	9.7	54	"
Boscia albitrunca	16.7	na	FAO, 1971
Boscia foetida	8.0	na	"
Colophospermum mopane	8.1	na	"
Combretum apiculatum	9.7	na	"
Combretum hereoense	10.7	50	APRU, 1985
Grewia bicolor	12.4	28	"
Grewia flava	12.5	49	"
Lonchocarpus capassa	12.4	na	FAO, 1971
Tarchonanthus camphoratus	10.9	53	APRU, 1985
Terminalia sericea	7.7	na	FAO, 1971
Ziziphus mucronata	12.0	61	APRU, 1985
Means	11.3	47*	

Note: APRU 1985 values are averages of 12 months and FAO 1971 are samples of April/May 1970.

*Means of eight species only.

establishment and persisted for years. Amongst the five *Cenchrus ciliaris* cultivars tested (Table 5), Western Australia did poorly in all the years. Mahalapye yields were better for *Cenchrus* sp. than those at Sebele. Mahalapye is in the central hardveld with average rainfall of 450 mm per annum, but Sebele is in the southern hardveld with a rainfall of 500 mm. At Sebele the

Table 4. Crude protein (CP) dry-matter digestibility (DMD) of some range woody plant leaves in the Kalahari sandveld, values in %.

Species	CP	DMD	Source
Boscia albitrunca	17.9	57	Skarpe[1]
Grewia flava	15.2	40	"
Grewia retinervis	16.3	55	"
Lonchocarpus nelsii	21.2	45	"
Tarchonanthus camphoratus	10.0	33	"
Terminalia sericea	7.0	37	"
Ziziphus mucronata	19.4	69	"
Means	13.1	48	

Note: Values are averages of 2 months, February and June 1977-1979.

[1]Skarpe, C. Gaborone, Botswana, unpublished data.

Table 5. Yield of some pasture species at Mahalapye and Sebele in kg per ha in 1978, 1979 and 1980.

	Mahalapye			Sebele		
Species	1978	1979	1980	1978	1979	1980
Cenchrus ciliaris						
cv Molopo	1192	4749			3948	4700
cv Biloela	2803	4153			3189	
cv Gayndah	1395	3623			1161	
cv U.S.A.	2790	4115			2698	5300
cv Western Aust.	Trace	Trace			Trace	0
Cenchrus sentigerus	670	Trace*			Trace	
Cynodon dactylon						
cv Giant Bermuda	799	1915*				
Eragrostis curvula						
cv Ermelo	4287	2509*			2709	
Urochloa mosambicensis	2855	2015*				
Panicum coloratum						
cv Bambatsi		2513*				1900
Siratro	1704	2802*			3528	1500
Phasey Bean	1093	2086*			7130	
Leichardt Dolichos	4165	3500				
Desmodium intortum						
D. uncinatum						
Dolichos lablab					5168	5000
Leucaena leucocephala						
cv Peru	550	2100				
cv Cunningham	420	2266				
cv Hawaian Cross	410	3233				
cv Hawaian Giant		2000				

*Production from plots planted the previous year.
Source: APRU (1978, 1979, 1980, 1981).

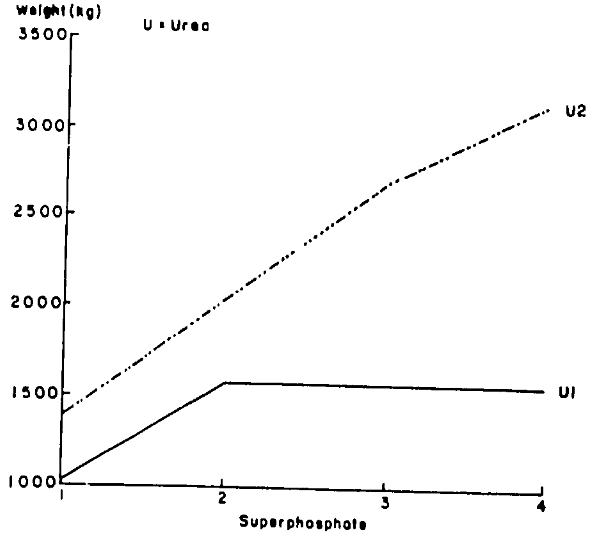
Cenchrus sp. established poorly due to heavy weed competition. The other grasses *Cynodon dactylon, Eragrostis culvula, Urochloa mosambicensis* and *Panicum coloratum* showed lower forage yields due to weed ingestation. There was however reasonable yields from *Eragrostis culvula, Urochloa mosambicensis* and *Panicum coloratum* especially at Mahalapye.

Amongst the legumes, *Macroptilium atropurpureum* cv Siratro, *Lablab purpureus* cv Leichardt and *Macroptilium lathyroides* established well and gave reasonable yields. Based on this work *Lablab purpureus* is now being grown in dairy farming systems project areas.

Leucaena leucocephala was established at Morale (near Mahalapye). The plant is susceptible to frost although it has shown the ability to regrow once weather conditions warm up. The major problem interfering with its successful establishment is white termite attack and wildlife and goats that hammer it hard, hence affecting its maintenance under range.

Results of the fertilizer trials indicated no significant increase in range productivity to levels of urea application beyond 50 kg/ha when phosphorus was held at zero. But when phosphorus was increased to 332 kg/ha the yield was increased at the other levels of urea application (Figure 1). Figures 2, 3 and 4 show yields of three grasses (*Digitaria, Eragrostis* and *Urochloa* spp.) in response to fertilizer. Nitrogen reduced yield at 500 kg/ha and beyond when superphosphate was held at zero (Figure 2). This response was similar to that of ammonium sulphate and potassium chloride, when ammonium sulphate was increased beyond 500 kg/ha and potassium chloride was held at 50

Figure 1. Response of rangeland yield to nitrogen and phosphorus.



kg/ha yield was reduced (Figure 3). Figure 4 shows that an increase in superphosphate increased yield more when potassium chloride was held at zero.

Figure 2. Response of rangeland yield to nitrogen and phosphorus.

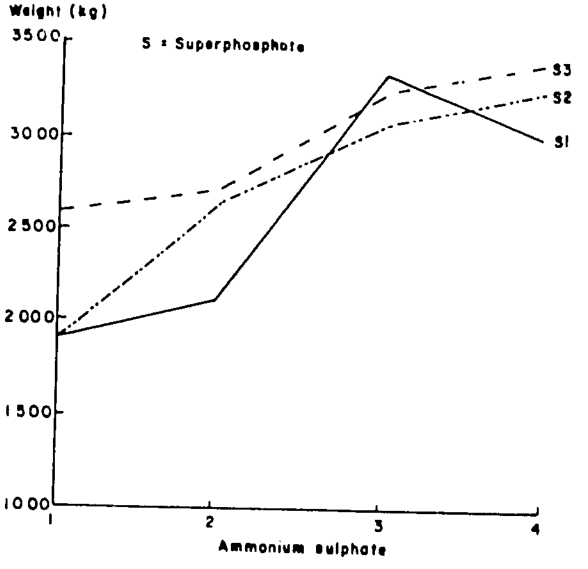


Figure 3. Response of rangeland yield to nitrogen and phosphorus.

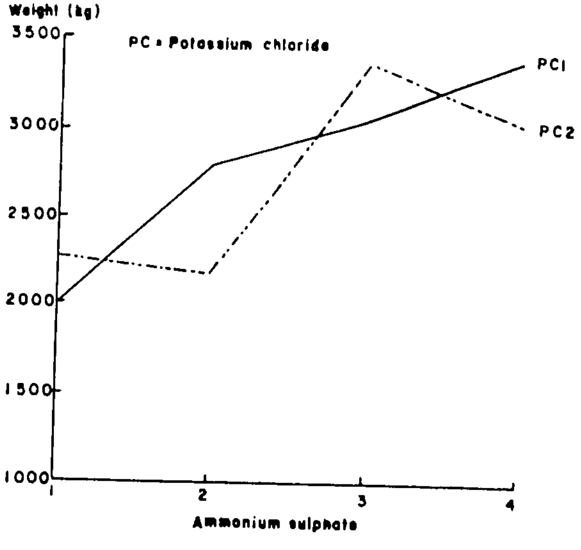
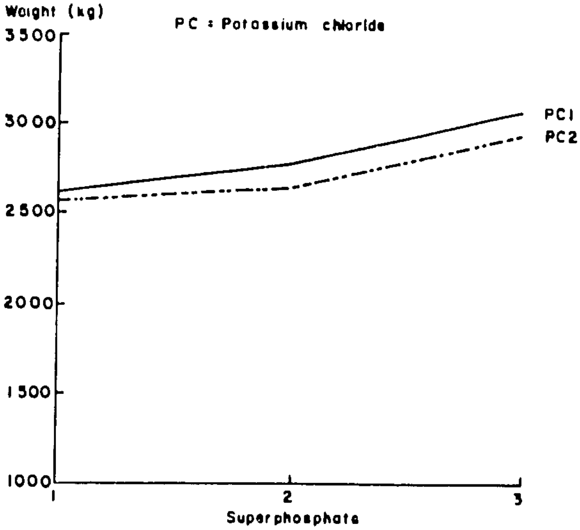


Figure 4. Response of rangeland yield to nitrogen and phosphorus.



DISCUSSION AND CONCLUSION

For Botswana, a country that has suffered from a succession of droughts, there appears to be limited scope for planted perennial pasture plants. Annuals render themselves better to easy incorporation in arable farming systems than perennials. The latter might pose problems of eradication in cropping systems.

Interest in fertilizer trials ought to be reduced as the economic feasibility has indicated that fertilizer application to the range is unlikely to be of practical value in the immediate future. The current trends in research are geared to collaboration with ICRISAT and ILCA to come up with various cultivars of fodder millets, fodder sorghums and some specialised grasses and fodder legumes that would easily fit in small-scale crop-livestock farming systems. Indigenous fodders ought to be an integral part of this work.

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DISTRIBUTION OF POTENTIAL FORAGE PLANTS IN MALAWI

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Abstract

The occurrence of grass species of Panicum, Pennisetum, Chloris, Urochloa, Setaria *and* Brachiaria *and legume species of* Neonotonia, Macrotyloma, Dolichos, Sesbania *and* Aeschynomene *in different physiographic regions is described. Emphasis has been put on the climatic variables which tend to influence species distribution and the physiological maturity among legume species.*

INTRODUCTION

Malawi, which is 94,396 sq. km, is dominated by the final section of the East African rift valley system which fractured the high south Central African plateau to form a deep trough occupied by Lake Malawi. The lake which is 570 km long and 16-80 km wide is drained by the Shire River following the line of rift into the Zambezi River (Agnew and Stobbs, 1972). The faulting and subsequent erosions created diversified topographies which have been modified by the influence of the lake, intertropical convergence zone and the southeast Trade Winds to give rise to tropical and sub-tropical environments. These environments contain a variety of grasses and legumes which could be utilised in our farming systems.

So far there has been no extensive plant collections in Malawi, and as a result detailed distribution of forage plants is rather sketchy. However, the few vegetation documents available, the 1981 collection strip made by the senior author to some parts of the central and northern regions and the knowledge of the authors has formed the bases of this paper. Consequently, some documents could have been overlooked out of ignorance.

The physiographic regions delineated by Pike and Rimmington (1965) (Appendices 1 and 2) have been used to describe the distribution of the forage plants. The climatic variables in these regions differ a lot and warrant a separate description to give a prospective collector all the necessary information.

INFLUENCE OF PHYSIOGEOGRAPHIC REGION

Lower Shire Valley

This area is a narrow extension of the Mozambique Coastal Plain into Malawi with altitudes ranging from about 120 m in the north to 40 m in the south. The area lies in the rainshadows of the Thyolo escarpment in the north-west, the Nsanje Hills in the south and the watershed between the Zambezi and the Shire rivers. The average temperature and rainfall are 30°C and 630 mm respectively.

Urochloa mosambicensis, Panicum spp. *Clitoria ternatea, Rhynchosia* spp. and *Sesbania* spp. are found in this area. *Urochloa mosambicensis* is widespread in the valley especially on grassy areas occurring on sandy soil. This ecotype is superior to *U. pullulans*, a perennial found elsewhere in the country at altitude below 1500 m which tends to scorch whenever there is dry spell during the rainy season. *Setaria* and *Panicum, Sesbania* and *Aeschynomene* spp. grow along streams and dambos. *Clitoria ternatea* is found around Ngabu on gravelly soils.

Mulanje Mountains - Shire Highlands - Zomba Mountain

This region whose average altitude ranges from 610 m to 3000 m has an extended rainfall season as a result of the moisture carried by the south-east Trade Winds from the Indian Ocean. Average rainfall is about 3000 mm in Mulanje and Zomba and decreases to about 1000 mm in some parts of the Shire Highlands.

Panicum maximum occurs along roads, streams and on scattered hills of the Shire Highlands which contain *Acacia woodii* and *Albizzia gummifera* vegetation. The commonest perennial wood type has broad dark green leaves and is found growing in the heavily disturbed areas. The giant types are found mostly on the windward side whereas the medium types tend to occur on the leeward side of these highlands. *Pennisetum, Setaria, Cynodon* and *Neonotonia* spp. also occur in this area.

Central Region Lakeshore Plain

This area extends from Salima in the south to Nkhota-kota in the north. It is a relatively dry area due to the prevalence of the southeast Trade Winds which lose their moisture on the Mulanje, Shire and Zomba Highlands. The altitude is about 500 m, and the average temperature and rainfall are 23°C and 1270 mm respectively. The area is characterised by seasonal swamps and *Acacia-Adansonia-Cordyla-Sterculia* vegetation - interspersed with alluvial fans along the Linthipe, Lingadzi, Bua, Kaombe, Dwangwa and Dwambazi rivers.

Panicum, Pennisetum, Cynodon, Brachiaria, Setaria, Neonotonia and Aeschynomene spp. occur in this area. *Panicum maximum* is found along river and swamp fringes. The *P. maximum* growing along the Dwangwa river could even be planted from setts. The distribution of *P. maximum* seems to indicate that seed originally came from higher areas of the Dowa-Ntchisi and Viphya highlands. This hypothesis is supported by the absence of *P. maximum* along rivers and dambos from the Chitala river going southwards, a section which does not have corresponding highlands further inland. The *Cynodon* spp. have head smut which limits their chance of being suitable for collections. *Neonotonia wightii* along the entire area shows a visual gradation from diploid to tetraploid types from south to north corresponding to the amount of rainfall received.

Dowa-Ntchisi Highlands

The area has some evergreen forests at altitudes of 1700 m due to the influence of orographic rains brought by the southeast Trade Winds. *Panicum maximum*, *Setaria* spp. *Pennisetum purpureum* and *Neonotonia wightii* are found in this area.

Past collections from this area yielded *Panicum maximum* cv Ntchisi. This giant guinea grass has broad bluish green leaves which makes it suitable for cut-and-carry, silage and grazing (Addy and Thomas, 1976). Ntchisi panic has found its way into Kenya (Bogdan, 1977) and Zambia (Anon., 1979). Ntchisi panic like most guinea grasses is mostly propagated by splits because seed harvesting is hampered by variability in seed maturation on the same panicle which quickly sheds or are eaten by birds.

Central Region Plateau

The central region plateau is the largest continuous surface in Malawi extending from the margin of the rift valley in the east to the Zambian border in the west. The altitude ranges from 970 to 1300 m with an average temperature and rainfall of 20°C and 800 mm respectively.

The vegetation consists of *Acacia-Piliostigma-Combretum* and *Brachystegia-Julbernardia* savannah woodlands on the Lilongwe and Kasungu plains respectively. *Panicum maximum* occurs along major rivers of Lilongwe, Lingadzi and Bua whereas *Brachiaria* spp. *Setaria sphacelata*, *S. longiseta* and *S. splendida* are found both on higher ground and dambos. *Setaria palustris* is found on dambos only. Most of these *Setaria* spp. are attacked by head smut (*Tiletia echnosperma*).

Macrotyloma spp. occurring on the Lilongwe plain consist of both annual grabrescent and pubescent types. The grabrescent type climbs onto the hyparrhenia and maize plants. This climbing attribute onto the latter could be utilised to improve the quality of maize stover for stall-feeding. *Macrotyloma axillare* occurs on the Kasungu plain but its small leaves would limit its usefulness as a forage legume. *Neonotonia* spp. which matures towards the end of the rainy season occurs throughout this region especially on termite mounds.

Viphya Lakeshore and Highlands

The altitude ranges from 500 m on the lakeshore to about 1300 m on the highlands. This region, apart from the Mulanje-Shire-Zomba highlands, receives the next highest annual rainfall of over 1500 mm. The southeast Trade Winds, after blowing over the lake for a long distance, get recharged with moisture which falls as orographic rain. As a result of this influence, this region has an extended rainy season which supports growth of low altitude evergreen forests on the lakeshore and on the highlands. The Luweya catchment area, the area between Chintheche and Nkhata-Bay and extending westwards to Mzuzu, has the largest variety of *Panicum* and *Brachiaria* spp. compared to any other area in Malawi. In contrast, the northern Viphya Highlands contain relatively few of these grasses probably due to the rainshadows created by Choma and Chimaliro hills within the highlands. *Setaria* and *Pennisetum* spp. also occur in this area. Most of these species are found along streams and on the extensive Limphasa dambo. The heavily smutted *Cynodon* spp. are found on the lakeshore only.

Neonotonia, Dolichos and *Macrotyloma* spp. occur in this region. Among *Neonotonia* spp. are found both early and late maturing ecotypes. The latter flower as late as August at the onset of the dry hot season when wild fires are very common. The slender pubescent *Macrotyloma* sp. is found on the lakeshore along gullies whereas *Macrotyloma axillare* and the shrub type *Macrotyloma* sp. occur on the highlands. *M. axillare* distribution seems to indicate that it thrives well on well drained sandy loam soil.

The Henga - Lower Kasitu Valley

The region lies between the Viphya to the west and Nyika plateau and Njakwa Hills to the east. The altitude is over 1000 m with an average temperature and rainfall of 21°C and 760 mm respectively. The vegetation consists of the *Brachystegia-Julbernardia* and *Combretum-Acacia* woodlands. *Chloris gayana, Cynodon* spp., *Panicum* spp. and *Neonotonia* spp. occur in this area. Most *Cynodon* spp. have head smut. *Neonotonia* spp. mature early in May-June at the onset of the cool dry season.

The Mzimba Plain

Most of the area lies in the rainshadows of the Viphya highlands, the Nyika plateau and the Njakwa Hills. The vegetation consists of the *Brachystegia-Julbernardia* woodland. The altitude is about 1200 m and the average temperature and rainfall is 20°C and 760 mm respectively.

Chloris gayana, Panicum spp., *Cynodon* spp., *Pennisetum* spp., *Neonotonia* spp. and *Clitoria ternatea* occur in this area. No collections of *Chloris gayana* have been made despite its wide acceptance for grazing and hay making. However, Vwaza Game National Park will remain the major area for future collections whereas in settled areas termite mounds will be the best spots. Large patches of *Cynodon* spp. in the Nkhamanga and Hewe areas occur along rivers and low lying areas. *Panicum maximum* is mostly found along the Rumphi and Runyina rivers. *Clitoria ternatea* is found at Rumphi boma.

Nchenachena-Livingstonia Hills

The area lies on the eastern slopes of the Nyika at an average altitude of 1400 m and is characterised by cool weather and an extended rainy season due to the influence of the southeast Trade Winds. The average annual temperature and rainfall is 20°C and 1700 mm respectively.

Neonotonia and *Dolichos* spp. occurring in this area mature late in September-October at the onset of the short hot dry season. The largest concentrations of *Neonotonia* spp. occur between Junju and Kaziwiziwi where it is possible to find plants 20 m apart. Medium and giant *Panicum maximum* are concentrated along rivers and valley bottoms. *Cynodon* spp. occurs at Rumphi North bridge and around the Livingstonia plateau.

The Nyika Plateau

The plateau lies between 2,000-3,500 m and receives about 1270 mm rainfall. The average temperature is about 14^{o}C. *Setarias* and *Macrotyloma* spp. are the only important forage species found on the plateau. The *Setaria* because of the altitude have very small leaves and may not be suitable for collections. Two types of *Macrotyloma* spp. occur in the plateau - the grabrescent type found in the open grasslands and the slender pubescent type is found among the dense thickets along valleys. Kikuyu grass (*Pennisetum clandestinum*) introduced from East Africa has almost been naturalised on the plateau.

The Karonga Lakeshore Plain

The lakeshore plain average altitude is about 550 m. The average temperature and rainfall are 25^{o}C and 920 mm respectively. *Setaria, Panicum* and *Brachiaria* spp. occur along channels in the Hara, Wovwe and Lufilya rice schemes, the dambos through which some major rivers from the Nyika plateau pass. *Cynodon* spp. on this plain are severely attacked by head smut. *Calopogonium* sp., growing around the Lufilya rice scheme, is a recent introduction by the Chinese agricultural technicians for green manuring.

The Chitipa-Lufilya Plain

The plain lies at an altitude of 1500 m. The average temperature and rainfall are 20^{o}C and 1000 mm respectively. *Panicum, Cynodon* and *Neonotonia* spp. occur in many areas especially along the drainage systems. Large concentrations of *Panicum maximum* are found at Chisenga, at the foothills of the Mafingi Hills, and a few plants are scattered along the Kaseye and Lufilya rivers. *Neonotonia wightii* is found along the Kaseye and Songwe rivers, and most of these mature in July. *Cynodon* spp. are widely distributed on the Chitipa plain especially on sandy soils where they form large patches of natural pastures. No head smut was observed on these *Cynodon* spp.

The Misuku Hills

The hills rise to an altitude of 2000 m. Due to the influence of the south-east Trade Winds, the area is covered by moist *Brachystegia* woodland, semi-evergreen forests and montane grassland forests. The average temperature and rainfall are 21^{o}C and 100 mm respectively. *Neonotonia wightii*, with a lot of hairs, occurs in this area and matures late in September. A *Calopogonium* sp. introduced by earlier agriculturalists grows around Misuku Agriculture Station. There are few *Panicum* and *Brachiaria* spp. in this area probably due to extensive cultivation in this densely populated area. *Cynodon* spp. occurs in scattered areas.

Summary and Conclusions

Panicum species tend to occur more in wet and fertile areas with high frequencies than in dry areas especially on the leeward side of high grounds. *Neonotonia wightii* also tends to follow the same pattern except that occurrence is also high in wet fertile areas. *Chloris gayana, Urochloa mosambicensis, Brachiaria* spp. *Dolichos* spp. and *Macrotyloma* spp. have special habitats. Therefore, with the present knowledge it is possible to make trips to targeted areas to collect specific species.

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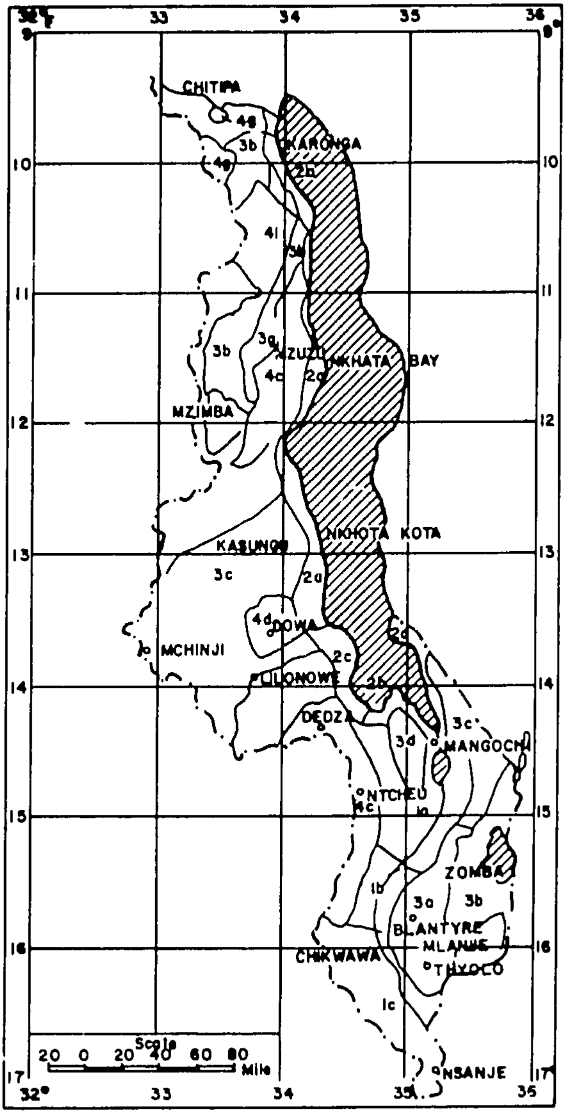
Appendix 1

Figure 1. Physiographic Regions of Malawi.



Legend of Physiographic Regions as shown in Figure 1.

1a	-	The Upper Shire Valley
1b	-	The Middle Shire Valley
1c	-	The Lower Shire Valley
2a	-	The South-eastern Lakeshore
2b	-	The Southern Lakeshore
2c	-	The South-west Lakeshore
2d	-	The Nkhota-kota Lakeshore
2e	-	The Viphya Lakeshore
2f	-	The Karonga Lakeshore
3a	-	The Shire Highlands
3b	-	The Lake Chilwa
3c	-	The Namwera Hills
3d	-	The Chitipa Plain
3e	-	The Central Region Plateau
3f	-	The Mzimba Plateau
3g	-	The Henga-Kasitu Valley
3h	-	The Nchenachena
3i	-	The Chitipa-Lufilya Plain
4a	-	Mulanje Mountains
4b	-	Zomba Mountain
4c	-	The Dedza-Kirk Range Highlands
4d	-	The Dowa Highlands
4e	-	The Viphya Highlands
4f	-	The Nyika Plateau
4g	-	The Mafingi Mountains
4h	-	The Misuku Highlands

THE DISTRIBUTION OF SESBANIA SPECIES IN THE PANESA REGION

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INTRODUCTION

The genus *Sesbania* belongs to the family Leguminosae and its subfamily is Papilionoideae. There are four subgenera of which *Sesbania* and *Agati* are of agricultural value. The subgenus *Sesbania* is much more important in Africa, and it has a large number of species. Some of the most important members of this subgenus *Agati* is mainly found in southern Asia and its members are more of perennial and tree types as compared to the relatively more annual and shrub types found in the subgenus *Sesbania*.

Members of the genus *Sesbania* are known for exceptionally fast growth rates as well as a very high affinity for association with several nitrogen-fixing Rhizobia in the soil that cause formation of numerous and large nodules in the plant roots. Members of this genus also have several potential uses including forage, poles for light construction, fuelwood, pulpwood, live fences, medicines, shade trees for other crops and gums. This paper reviews these potential uses and makes a strong case for germplasm collection of members of the genus *Sesbania* in the PANESA region. It is envisaged that such a collection from several African countries will yield many useful selections when it will be subjected to screening for various economic and agricultural traits.

SPECIES OF SESBANIA

Fifty species of *Sesbania* have been described in tropical and subtropical regions of the world. Thirty-three of these species are found in Africa (Table 1). The remaining 17 species are found in Australia (10) and Hawaii (7) species (Gillet, 1963; Burbidge, 1965). The number of Asian species is not known (Char, 1983).

In Africa the most dominant species is *S. sesban (S. egyptica)*. However, there are several species of Sesbania in Africa with unknown agricultural value and these have not been evaluated in agronomic trials. *Sesbania* has been reported in virtually all African countries from the tropical rainfall forests in Zaire to the Nile valley in the Egyptian desert.

Table 1. Species distribution of Sesbania in various regions of the world.

Region	No. of species	Source
Africa	33	Gillet, 1963
Australia	10	Burbidge, 1965
Hawaii	7	Char, 1983
Asia	Unknown	Char, 1983

Objectives of the proposed *Sesbania* collection include:

1. To obtain *Sesbania* species from countries in the PANESA region. The seeds will be divided into two portions, one portion to be taken to a PANESA germplasm collection, and the other portion to be given to each country where the collection was made.

2. The collections to the PANESA germplasm bank will not be an idle gene bank, but rather an active working collection. The collection will be screened for several potential, agricultural, forestry and industrial and medicinal uses.

3. The information will be catalogued by the co-ordinator of PANESA.

4. Arrangements will be made to multiply seeds of the promising collections and make these available on request to PANESA member countries.

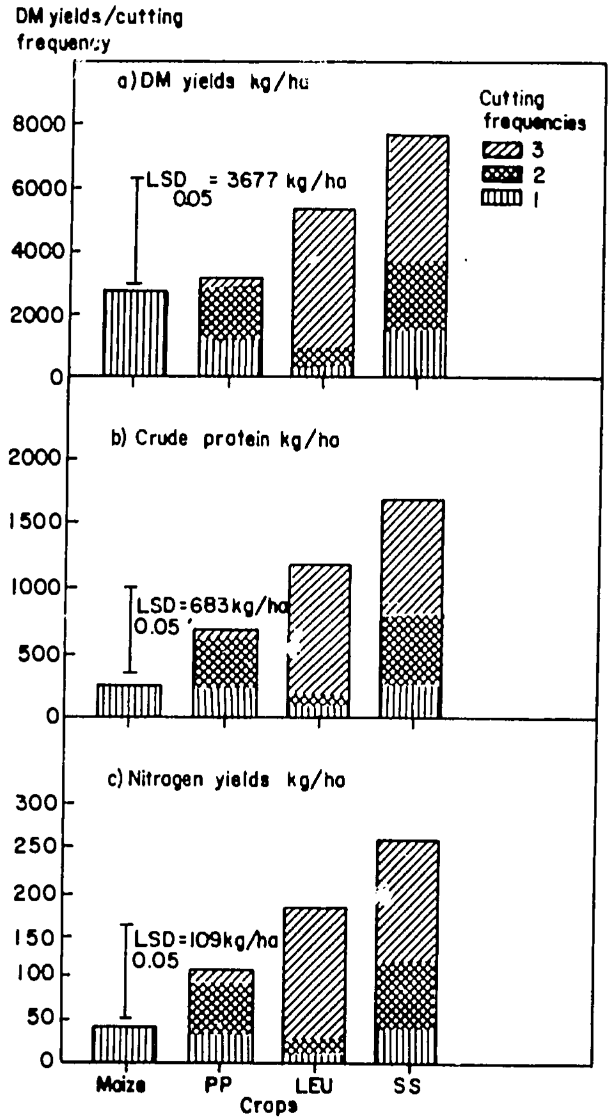
AGRICULTURAL USES OF SESBANIA

Livestock Feed

Several *Sesbania* species are an excellent livestock feed, both as fodder and hay (Onim *et al.*, 1985). Dry-matter (DM) yields of *Sesbania* forage is quite high when compared to other forage legumes. Onim (1986) compared forage productivity of *Leucaena leucocephala* (cv Cunningham), pigeon pea (*Cajanus cajan*) and *S. sesban* at Maseno Research Station in western Kenya. The forage DM forage yields of the legumes after six months from planting were 8000, 5500 and 3000 kg/ha for *Sesbania, Leucaena* and pigeon pea respectively. Similarly nitrogen yields of these legumes were 250, 175 and 120 kg/ha for *Sesbania, Leucaena* and pigeon pea respectively (Figure 1).

Nutritive values of forages of some *Sesbania* species are presented in Table 2. The range of CP in Table 2 is from 18.8% to 32.0% with a mean of 27.1%. The mean crude fibre content is low (13.0%) and the mean calcium to phosphorus ratio is high (3:8). It is therefore clear that *Sesbania* species have forages of very high quality. Results of Katiyar and Ranjham (1969), Chinnaswami *et al.* (1978) and Singh et al (1980) showed that digestibility coefficients of three *Sesbania* species were quite consistent when these were fed to sheep and goats (Table 3). DM and CP digestibility coefficients had means of 69.7 and 80.6 respectively. These results compare well with the DM

Figure 1. Cumulative DM, crude protein and nitrogen yields of maize, pigeon pea, leucaena and sesbania after three cuttings.



digestibility coefficient of 74.3 that was reported on *S. sesban* from Maseno, Kenya by Sidahmed et al (1984). The high nutritive value of *Sesbania* forage was confirmed in a supplementation study at the International Livestock Centre for Africa (ILCA) in Ethiopia (Anon., 1986). In this study, teff (*Eragrostis tef)* straw was supplemented with leaf hays of three browse tree legumes - *Acacia cyanophylla, A. seyal, S. sesban* and *Vicia dasycarpa* on a sheep feeding trial. Sheep body growth rates

Table 2. Nutritive values of forages of some *Sesbania* species (% DM).

Species	DM	CP	CF	Ca:P ratio
S. exaltata	26.3	18.8	12.4	4.9
S. bispinosa	23.8	30.0	11.4	2.4
S. sesban	25.8	26.0	16.2	6.8
S. macrocarpa	24.3	31.2	14.2	2.9
S. cinerascens	26.1	23.6	12.6	3.1
S. mosambicensis	25.2	32.9	10.9	1.9
S. grandiflora	18.1	26.9	12.3	4.5

Source: Rotar and Evans (1985).

Table 3. Digestibility coefficients of *Sesbania* materials as reported in several studies.

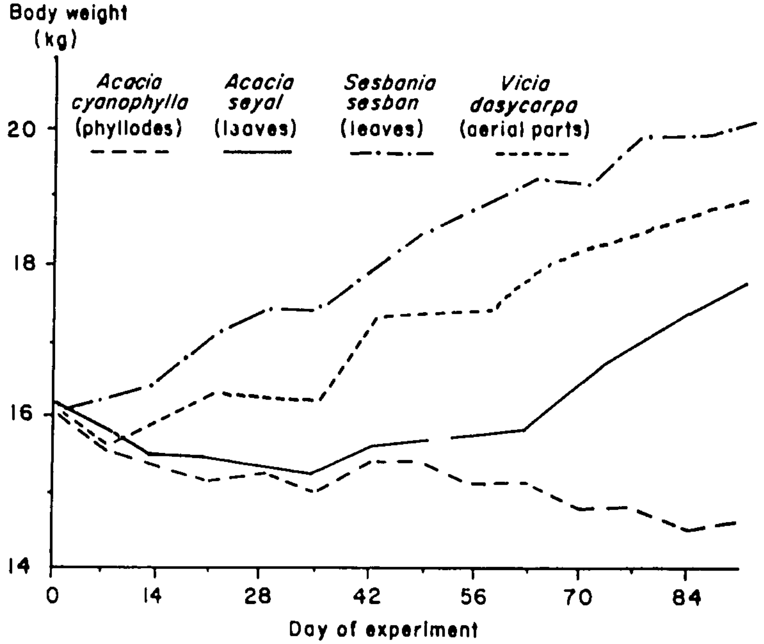
	A *S. bispinosa* 15,7 adult rams	B *S. sesban* 45,7 kid goats	C *S. grandiflora* 10,7 adult rams
Dry matter	74.0	69.53	65.65
Crude protein	82.1	80.80	79.03
Ether extract	33.9	13.58	18.24
Crude fibre	63.7	56.13	57.30
N-free extract	75.9	67.82	68.60

Sources: Katiyara and Ranjhan (1969); Singh *et al.* (1980); Chinnaswami *et al.* (1978).

showed that *S. sesban* hay was by far superior to all the other legumes: in fact sheep on *A. cyanophylla* supplementation lost condition (Figure 2a). Nitrogen balance in sheep showed that apart from *cyanophylla*, the other legumes were ranked for the amount of nitrogen retained as *Vicia dasycarpa, Sesbania sesban* and *Acacia seyal* (Figure 2b).

These excellent nutritive qualities, especially the high CP content, makes *Sesbania* a very useful supplement as a source of CP to livestock. This is particularly crucial in small-scale farming where feeding of crop residues or cut-and-carry systems require a readily available source of CP. *Sesbania* hay lends itself to this system very well because it is easily stored until it is needed. Dairy meal (CP = 15%) can easily be substituted with *Sesbania* hay as a source of CP (CP = 26%) to lactating dairy animals.

Figure 2a. Growth rates and nitrogen balance of sheep fed foliage from three different fodder trees or retch hay as supplements to teff straw.



Source: ILCA Annual Report (1985/86).

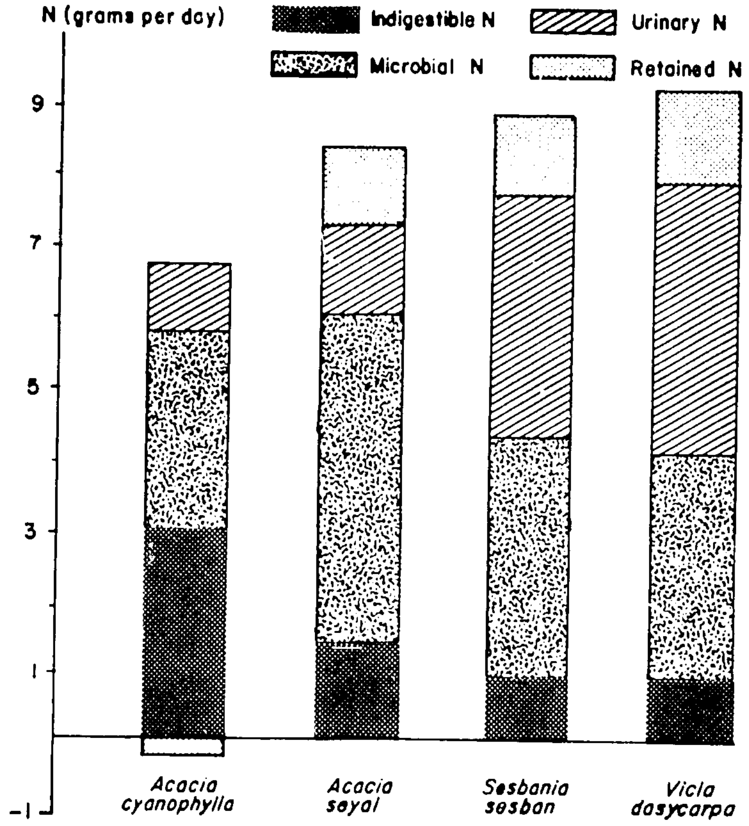
Improvement of Soil Fertility

Sesbania species are known to fix between 500 to 600 kg/ha of nitrogen per year. In a green manure experiment in Maseno, Kenya (Onim, 1986) reported that *S. sesban* fixed up to 250 kg N/ha in six months. Since urea fertilizer contains 46%N, this fixation is equivalent to approximately eleven 50-kg bags of urea fertilizer in six months. The use of *Sesbania* as a green manure (GM) crop is a common practice in southeast Asia. Several studies have shown that *Sesbania* can return into the soil as GM between 80 and 120 kg of N within 90 days (Dargan *et al.*, 1975; Bhardwaj *et al.*, 1981).

Sesbania species are also often used in land reclamation especially in salty (saline) and sodic soils as well as in mining and excavation sites (Srivastava *et al.*, 1973; Malik and Haider, 1977). Both *S. bispinosa* and *S. sesban* have been used for these purposes.

S. rostrata is native to tropical West Africa. This species is unique because it fixes nitrogen not only in its roots in the soil, but also in its aerial parts including stems and branches.

Figure 2b. Nitrogen balance in sheep.



Research on this symbiosis in *S. rostrata* and its agronomic implications has been conducted by scientists at the office of Scientific Research Techniques, Outre-Mar, at the Scientific National Research Centre in Senegal, Sudan, Zaire, Malawi, Zimbabwe, Botswana, Caprivi Strip and Malagasy Republic (Gillet, 1971). Whether this species can fix more nitrogen than the other species is not well documented. More research is required in this area.

Increased Milk Secretion

As far back as the 1930s, lactating mothers in Java were encouraged to eat young pods and flower buds of *S. sesban* and *S. bispinosa* since it was believed that these stimulate milk secretion (Ochse, 1931). This galactagogue effect has also been reported in cattle in Kenya where in the 1950s, *S. sesban* was referred to as "milk shrub" (Brown, 1954). Farmers were encouraged to feed *Sesbania* fodder to lactating cows to enhance milk secretion.

General Uses

Apart from the above-mentioned agricultural uses, there are several other general ones. These include cases where *Sesbania* are used as shade trees in coffee, cacao and other crop fields; as live fences and for general agroforestry uses.

INDUSTRIAL AND DOMESTIC USES

Fuelwood

Perennial *Sesbania* species have been used for many years as a source of fuelwood. Bulk density of *Sesbania* varies according to species, rate of growth and age. However, values ranging between 240 to 616 kg/m^3 have been reported (NAS, 1980 and 1983). Fuelwood yields also vary depending on plant population used, species and bulk density. For example, *S. grandiflora* in a replicated trial in four sites in Hawaii at a spacing of 90 cm x 90 cm (12,346 plants/ha), the trees had a mean stem diameter of 9 cm at breast height, and after three years the trees averaged 8 m in height (MacDicken, 1983). In another trial, at one year of age *S. grandiflora* had a height of 3.3 m, mean basal area of 24.5 cm^2 and mean estimated wood volume of 24.6 m^3/ha.

S. sesban grows to a height of approximately 4.0 m a year in western Kenya. Fuelwood potential of perennial *Sesbania* species among rural peoples of Africa is very large. This genus has many beneficial contributions to the environments where its forests are established for fuelwood purposes. These include its ability for rapid growth and thereby giving ground cover against soil erosion, leaf fodder for livestock and improvement of soil fertility through biological N-fixation and leaf litter. It is therefore imperative that this genus be strongly encouraged in soil reclamation, fuelwood and soil fertility improvement programmes in African developing countries.

Fibre and Pulpwood

Sesbania species have also been used for fibre and pulpwood extraction. The *S. exaltata* of the Americas has been used as a source of fibre for fishing nets and lines by the Yuma Indians of Arizona for many centuries (Parker, 1972). In South East Asia, *S. bispinosa* has been used for the same purpose (Sircar, 1948). *Sesbania* fibre has been found suitable for fish nets because it resists decay. This quality qualifies *Sesbania* fibres for several other marine applications like sail lashings. *Sesbania* fibre is stronger than jute fibre (Townsend, 1973).

Sesbania has also been used as an important source of pulpwood. The best species for this role are *S. sesban, S. grandiflora* and *S. bispinosa*. The same bulk densities referred to before under fuelwood also apply here. When planted at a spacing of 20 cm x 40 cm, up to 125,000 stems/ha can be harvested. A paper mill exclusively operating on *S. bispinosa* did well in west Pakistan (Hussain and Ahmed, 1965). In India, plantations of *S. sesban* have been established at Dandeli, Karuataka and at Jajahmundry to be sources of pulpwood for the West Coast Paper Mills and Andra Pradesh Paper Mill respectively. Yields of between 50 to 55 tonnes of green wood/ha/year have been reported in these plantations (Dutt *et al.*, 1983).

Most of the African countries rely on pine forests for their pulpwood. Pines take up to 10 years to mature, and logs are often hauled into paper mills from as far as 400 km away (e.g. in Kenya). This makes operational costs extremely high. The potential of rapidly growing species like *Sesbania* and *Leucaena* offer attractive alternatives. Both of these genera are also N-fixing trees as well as an excellent high protein fodder and hay for livestock feeding.

Human Food

S. grandiflora is known on both the continent and islands of Southeast Asia for its large and edible flowers. Raw or lightly steamed after removing calyx and pistil, they are used as an ingredient of soups, salads and vegetable dishes. The white flowers are preferred in the Philippines since red ones are said to be bitter. Leaves are also cooked as a vegetable. In Sri Lanka, one method of preparation is to cook chopped leaflets of *S. sesban* with chopped onions in coconut milk, creating a vegetable component of a traditional rice-based meal. *S. grandiflora* leaves have been found to be bitter in trials in India (Bai and Devadas, 1973). *S. grandiflora* leaves had therefore to be prepared in mixture with other leafy vegetables (Gopaldas *et al.*, 1973).

Sesbania leaves and pods have been eaten by lactating mothers to stimulate or increase milk secretion (galactagogue). Ochse (1931) reported that in Java, leaves and young pods of *S. grandiflora* are eaten, especially by nursing mothers. According to Brown (1954), feeding *S. sesban* leaves to cattle is believed to increase their milk production. Hurov (1961) calls *S. sesban* the "Kenya milk shrub". The Haya people of western Tanzania use this species for the same purpose.

Sources of Gums

Many *Sesbania* species contain gums which may be of potential value for industrial uses. Natural gums, or mucilages, are complex polysaccharides which have a wide range of uses. Their varying physical properties are attributed to differences in the degree of branching of and polymerisation of the sugars. Gums are used in such wide-ranging products as ice cream, candy, soft drinks, beer, pastries and heat-and-serve convenience foods. Gums are also used in the manufacture of paper, textiles, paints, in well drilling and in mineral assay.

Burkill (1935) reported that gums obtained from *S. sesban*, *S. formosa* and *S. grandiflora* are very similar to gum arabic. A United States National Academy of Sciences Report (NAS, 1979) stated that *Sesbania* bark gums have been used as a substitute for gum arabic, and suggested that with increasing scarcity of gum arabic from *Acacia senegal*, exploitation of *Sesbania* bark gums should be encouraged.

MEDICINAL USES

Sesbania species have a long list of medicinal uses among different peoples of the world, especially in Africa and Asia. The three most important species as sources of traditional medicines are *S. sesban, S. grandiflora* and *S. bispinosa*.

Astringent

S. grandiflora juices and extracts have astringent quality. This is the ability to contract body tissues and blood vessels. This property is used for reducing fevers and for promoting fluid discharge and subsequent drying of mucous membranes, hence leading to healing of, for example, wounds. For systemic disorders e.g. smallpox, decoctions are taken internally. Local applications are claimed to bring relief to nasal congestion, and rhinitis and associated headache (Watt and Breyer-Brandwijk, 1962). The bark extracts are used in Java for thrush and stomach trouble in infants (Burkill, 1935). Astringent quality in *S. sesban* is even stronger and unique in many ways. Fresh root and poultices of leaves have been used for scorpion stings, boils, abscesses, rheumatic swelling and hydrocele (a collection of watery fluid in a cavity of the body, especially in the scrotum or along the spermatic cord). Diarrhoea and excessive menstrual flow are said to be relieved by a concoction of seeds.

Antihelminthic

Doses of up to 2 oz. of concoction of *S. sesban* leaf are used as an antihelminthic against tapeworms and roundworms in humans. A mixture of ground seed and flour made into a paste is used for treating ringworms (Watt, 1983).

Antibiotic

The Haya people of western Tanzania make a concoction of leaves, barks and roots called "Mubimba" from *S. sesban* that they use to treat a wide range of diseases including sore throat, gonorrhoea, syphilis, yaws, fits and jaundice (Watt and Breyer-Brandwijk, 1962).

Contraceptive and Arborifacient

It is believed in India that eating flowers for three days during menstruation inhibits conception. To prove this belief, Pakrashi *et al.* (1975) fed 50 gm of flower extract of *S. sesban* per kg of body weight to breeding and pregnant mice. Those that were breeding did not conceive while those that were pregnant aborted ranging from 54-77%, depending on the type of extract.

Antitumoric

Antitumor activity has been reported for the North American species (*S. drummondii*) and brief reviews of this work have recently been published in popular scientific press (Garmon, 1983). This characteristic was revealed when Powell *et al.* (1976) reported that ethanolic seed extracts of *S. vesicaria*, *S. punicea* and *S. drummondii* were cytotoxic in the KB cell culture and were active against lymphocytic leukemia P-388 in mice. The active ingredient in this extract was named "sesbanine" by Powell *et al* (1979). A further fractionation revealed a second active ingredient called "drummondol" (Powell and Smith, 1981). This antitumor medicinal value is of great interest in medicine as a possible source of drugs for cancers. The major limitation, however, is the very low yields of these compounds from *Sesbania* seeds. Approximately 450 kg of seeds yield a mere 50 mg of sesbanine (Powell *et al.*, 1979). However, work is in progress to produce synthetic sesbanine.

CONCLUSION

Several potential uses of *Sesbania* species have been reviewed in this paper. Most of these potential uses are urgently needed by the developing nations of Africa and Asia where populations are increasing at a rate that outstrips supplies from available natural resources. Since Africa has the largest diversity of *Sesbania* species, it is envisaged that the proposed germplasm collection when done, screened and catalogued will prove to be a great resource for the poor and developing nations in the PANESA region and beyond.

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SESSION II: FORAGE GERMPLASM EVALUATION

FORAGE GERMPLASM AT THE INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA

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Abstract

The International Livestock Centre for Africa (ILCA) holds a large collection of forage germplasm of legumes, grasses and browse in controlled storage conditions at its headquarters in Addis Ababa. The germplasm collection is a major responsibility of the forage agronomy programme at ILCA. The forage germplasm available and its storage is described. The types of data recorded about each accession and how to use these data to select suitable germplasm for screening activities is explained.

INTRODUCTION

The success of a forage research or development and improvement programme is usually dependent on the availability of adapted, productive and appropriate forage germplasm for selection of promising lines. In most African countries such germplasm has been difficult to obtain in the past because the sources were in institutions with no particular interest in or responsibility for forage development in Africa.

It was in recognition of this serious impediment to forage development in Africa that the Forage Agronomy Group (FLAG) at ILCA Headquarters in Addis Ababa established a forage genetic resources collection as a service to collaborators and other research workers in national programmes in Africa and for forage development work in ILCA programmes. This collection was begun in 1982 and has grown over the past five years until it now contains 9166 accessions of forage species, including legumes, grasses and browse.

The maintenance of such a large and varied collection is now a major responsibility of FLAG, which has accepted the international responsibility to store this germplasm and make it freely available for research and development. All original material is being duplicated in other forage genebanks for security under the IBPGR global network of base collections (Hanson *et al.*, 1984).

THE GERMPLASM COLLECTION

The germplasm collection is composed of about 75% legumes and 10% each of grasses and browse with 111 genera and 341 species represented in the collection. The major part of the collection is made up of experimental lines of germplasm which were either acquired from other institutions or original collections of forages from various countries in Africa, including Ethiopia, Kenya, Rwanda, Niger, Burundi, Eastern Zaire, Mali and Tanzania.

Due to FLAG being located in Ethiopia and the resulting ease and economy of collection there, the largest number of ILCA collected accessions are Ethiopian, and they constitute 30% of the total collection. FLAG collecting missions in the other countries have contributed a further 10% of the accessions. Commercial lines of legumes and grasses make up about 5% of the collection and are held as a service to users who wish to test commercial lines in small quantities for preliminary evaluation.

Due to the great range of environments in ILCA's mandate region and due to the centre of diversity of many important legumes lying outside Africa, primarily in South and Central America and Asia, FLAG has made considerable efforts to acquire representative sets of germplasm of potential value for development in Africa from institutes with collections from these regions. Almost 20% of the collections were obtained from the Centro International de Agricultura Tropical (CIAT) based at Cali in Colombia which has a large collection of legume germplasm from Central and South America, the main centre of diversity of forage legumes. FLAG has strong co-operative links with the staff of the tropical pastures programme at CIAT, and in the past CIAT and ILCA have held joint collection missions for forages in Africa. Another major donor of germplasm has been the Division of Tropical Crops and Pastures (CSIRO) based in Queensland, Australia from whom ILCA has received almost 10% of its germplasm. The remaining accessions have been acquired in smaller numbers from other research organizations, from individual scientists or as duplicates of materials held by ILCA's field programmes in Nigeria and Mali.

IMPROVING THE COLLECTION

Despite the number of accessions already in the genebank, there is much variation in both exotic and native African species of recognised forage value which is not represented in the collection. In addition, there are more than 50 of the 111 genera held by the genebank which are as yet only represented by very few accessions. These genera cannot be usefully tested with such a narrow range of material.

African germplasm of forage potential has been little explored, and legumes, grasses and browse can be profitably collected. Concentration of collection activities in individual species and genera has captured tremendous genetic variation, for example in the East African highlands, *Trifolium* species (collected by ILCA), *Brachiaria decumbens* (collected by ILCA-CIAT) and *Panicum maximum* (collected by ORSTOM).

Genera worthy of attention in Africa due to their diversity, include among others the legumes *Macrotyloma, Lablab, Aeschynomene, Crotalaria*, the browse *Sesbania, Erythrina* and *Acacia* and many species of grasses, including *Digitaria, Pennisetum, Cynodon* and *Chloris*.

Forage species are also needed for development for specific African environments. For example there are few truly promising legumes for semi-arid and acid soil conditions. Browse germplasm is very limited for acid soils and high altitudes. Such germplasm may be obtainable from other genebanks, or collections may have to be undertaken within or outside of Africa.

There is an urgent need to collect and preserve genetic variation in species with genetic potential from areas subject to rapidly increasing population pressures before they are lost due to the resulting drastic environmental changes. Genetic erosion in forages and other wild species is occurring at a rapid rate in many areas, and timely action to collect is essential if valuable germplasm is not to be lost.

Due to the small amount of forage germplasm collection done to date in Africa, almost any well planned collection is bound to produce new and substantial variation. Collecting missions require considerable forward planning to be successful. The target species, area of collection and time of year must be defined in order to optimise the number of accessions obtained. In 1987 FLAG has planned two collecting missions. One is genus-specific to collect mainly *Sesbania* species in Tanzania during July to August, although other genera of interest will also be collected if time allows. The other is a more general Ethiopian browse collection mission, which will probably be split into several short missions beginning in May to cover the seeding period of many species.

STORAGE OF MATERIAL

The material collected must be conserved in an appropriate manner so that it remains available for distribution and is not lost or merely stored without being utilised. The easiest storage method is in a seed genebank. ILCA has recently installed new drying and cold rooms to process and store seeds under conditions in line with the IBPGR recommendations for the storage of seeds in genebanks (IBPGR, 1985). Seeds are first dried to between 3-7% moisture content in a dehumidified drying room, which operates at 15°C and 20% relative humidity. Under these conditions small seeds reach the required moisture content within one week while larger seeds take up to two weeks. When the seeds are dry they are packed in moisture-proof laminated aluminium foil bags which are carefully labelled and placed into store. ILCA has two types of germplasm storage. The active collection, composed of larger seed samples for distribution, is stored in a cold room at 5°C. The base collection is for security storage only and is stored in deep freezers at -20°C.

Another method of conservation is to maintain plants in field genebanks. ILCA has a field genebank in the Rift Valley where a large collection of *Brachiaria* species and some other grasses are planted out. Many grass species rarely produce viable seeds and at ILCA maintenance in plots is the only feasible way to conserve these species. *In vitro* genebanks, where meristem cultures are maintained in test tubes under controlled environmental conditions, are an alternative method of storage of species which do not readily produce seeds. FLAG is already culturing meristems of *Brachiaria* species for distribution, and work will begin later this year on methods of culturing other grass genera and the development of *in vitro* storage procedures.

GERMPLASM DATA

In order that germplasm can be efficiently utilised, basic information should be available about each accession, thus allowing selection of potentially adapted materials for specific ecological zones. At collection, as much useful field data as possible is recorded about each accession and the site where it was collected. In genetic resources terms this data is known as passport data. A standard collecting form is used to record the data (Lazier, 1985) which is then entered into the computerised database. More data is obtained from references and analyses of soil samples. Further identification of herbarium specimens may be necessary. The database which ILCA uses has been made as comprehensive as is practical in order that a maximal amount of data is available to researchers.

Another set of data known as preliminary characterisation data is recorded when the material is first grown in the field. This is, in general, observation data on morphology and adaptation obtained from a small number of plants in unreplicated plots. Further evaluation in replicated strip trials provides agronomic data which allows selection of promising material for multi-site evaluation trials in national programmes.

To date only the passport data has been entered into the germplasm database, but it is envisaged that a supplementary database of agronomic characters will also be established in the development of the genebank documentation system. The computer is a valuable tool in germplasm work because it allows rapid selection of subsets of accessions by query on specific fields, preparation of germplasm catalogues and lists of passport data and manipulation of data.

HOW TO SELECT GERMPLASM FROM THE GENEBANK

With such a wide array of germplasm available, the user may find it very difficult to select accessions for evaluation. The forage agronomists in FLAG can provide advice on promising materials to test, but selection is also possible directly by the user. FLAG publishes a germplasm catalogue which is updated at regular intervals (ILCA, 1985). This lists all accessions available in the genebank in three ecologically organised volumes: tropical lowland, temperate/Mediterranean and tropical highland. The accessions in each volume are divided into annual and perennial legumes and grasses and presented in alphabetic and accession number order. A section on browse species is included in the tropical lowland germplasm catalogue, since the majority of the multi-purpose tree species are of tropical origin. As our collection expands with the addition of more temperate materials, sections on browse may be added to other catalogues.

Since the catalogue cannot contain all useful data on an accession because of the amount of data available and large number of accessions, only the fields most useful for selection of appropriate germplasm for evaluation were included in the catalogue. This includes collection site data such as geographic location, rainfall, soil type and pH and other identification numbers of each accession.

The catalogue can be used to select annual or perennial accessions of species of interest which were collected from areas of similar environment to the trial site. Users can then fill the ILCA numbers of selected lines onto an ILCA seed request form and submit this to FLAG.

Germplasm is freely available from the FLAG genebank in small experimental quantities of a few seeds to a few grams. The recipients must multiply seeds of any promising material for use in subsequent experiments themselves. In return for the seeds, recipients are requested to provide the genebank with information on the performance of the lines tested, in order that the genebank can provide adapted germplasm for similar environments with greater assurance, thus providing a better service and considerable savings in time and labour.

WHAT GERMPLASM TO SELECT

It is obvious that with the wide range of environments encountered in sub-Saharan Africa, that sets of adapted germplasm must be developed for different ecological situations. FLAG currently evaluates its germplasm in four major environments. Three are in Ethiopia: tropical subhumid, mid-altitude on acid soils, tropical semihumid highland. More recently evaluation was commenced on tropical sub-humid lowland acid soils in Nigeria. Over the last four years a series of trials have been carried out in the Ethiopian sites and promising experimental materials have been selected for each of these environments. These are then planted in larger plots to see if they maintain their comparative advantage compared to commercial or previously available lines and to obtain sufficient seeds for larger scale trials. FLAG is building up its stocks of seeds of promising accessions so that they can go into wider testing in national programmes in 1988. Collaboration with national research centres through PANESA is the next important step in the development of promising forage germplasm for utilisation in animal production systems in the region.

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A REVIEW OF THE POTENTIAL OF *BRACHIARIA* SPECIES AS FORAGE CROP FOR LIVESTOCK IN TANZANIA

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Abstract

Brachiaria *spp. is a perennial grass native to East and Central Africa. It has been introduced into humid tropical regions of Latin America, southeast Asia, and northern Australia where it has revolutionised grassland farming and animal production. The potential of* Brachiaria *spp. in its native land on the other hand, remains largely unexploited.*

About 99 percent of Tanzania's ruminant livestock population (22.5 million head of cattle, sheep and goats) derive all their feed from pastures. Hence, there is need to explore productive native pasture species and to provide high management practices so as to increase their yield and quality. The impressive results recorded on Brachiaria *in foreign lands, together with a few experimental results recorded in East Africa, indicate that this species could have a significant impact on animal production in East Africa.*

This paper therefore reviews research work carried out in Tanzania on Brachiaria *spp. in order to stimulate more research on this species.*

INTRODUCTION

A number of *Brachiaria* spp. have been recorded in East Africa. These are *Brachiaria brizantha, B. ruziziensis, B. serrifolia, B. mutica, B. dictyoneura, B. nigropedata, B. soluta, B. humidicola, B. radicans, B. serrata, B. jubata, B. leucocrantha, B. platynota* and *B. bavonei*, (Bogdan, 1955; Van Rensburg, 1960; Mengistu, 1985). The most common of these species are *B. brizantha* (Signal grass), *B. mutica (Para grass), B. ruziziensis* (Congo grass).

Brachiaria brizantha occurs throughout tropical Africa from sea level up to 2400 m under an annual rainfall of over 800 mm (Bogdan, 1977). In East Africa, Bogdan (1955) reported that *B. brizantha* is very variable and several varieties show striking differences in habit morphology and seed setting capacity. It is possible that the different varieties will perform differently in different ecological zones, but information of this kind is lacking. Low seed viability is probably one of the chief limitations to the wide use of *Brachiaria* spp. as a forage crop. Identification and development of varieties with good seed setting capacity is one area that ought to receive attention from researchers. *B. brizantha* has also been noted to be resistant to drought and aggressive, competing effectively with other species and quickly covering the ground (Stomayor-Rios *et al.*, 1960). At Morogoro, Tanzania, a field of *Brachiaria brizantha* has been maintained for over 20 years without replanting. In Sri Lanka, *Brachiaria brizantha* has also been reported to perform well under shade of coconut trees (Anker-Lagefoged, 1955). This observation is relevant to Tanzania because a number of dairy and beef farms have been developed in coastal regions where inclusion of this species under coconut trees would greatly improve feed quality and quantity.

Brachiaria brizantha has also been noted to grow and give higher yield when grown on acid rather than alkaline soils (Sotomayor-Rios *et al.*, 1960). This characteristic makes it suitable to grow in fallow land after a continuous use of soil acidifying fertilizers such as ammonium sulphate. According to Bogdan (1977), this grass also recovers well from close cutting. This is also supported by observations on fields grown at Morogoro. These attributes make *Brachiaria brizantha* potentially suitable for the cut-and-carry feeding systems in highland areas of Tanzania. Due to its poor seed-setting characteristic *Brachiaria brizantha* is normally propagated by use of root stocks. This method of propagation is rather laborious for large-scale establishment but is not a major limitation for smallholder plots.

Brachiaria ruziziensis (Congo grass) is a leafy semi-prostrate, rhizomatous species adapted to humid tropics (Whiteman, 1980). It is less vigorous than Para and Signal grasses. It appears to be more shade-tolerant than Signal grass and thus is more suitable for inclusion under coconut trees. The grass can be propagated both from root stock as well as from seeds.

Brachiaria mutica (Para grass) is a perennial stoloniferous grass widely grown in the humid tropics and subtropics with rainfall of 1250 mm p.a. This grass has become the backbone of the beef industry in South and Central America, Australia, Philippines and Cuba (Bogdan, 1977). This species is, however, attacked by spittle bug in these areas, and attempts have been made by CIAT to collect germplasm resistant to spittle bug from East Africa. *B. mutica* is also said to perform well in waterlogged and flooded conditions as compared to *B. brizantha* and *B. ruziziensis*. This makes the species particularly suitable for swampy areas. *B. mutica* forms an open sward and therefore can combine well with legumes particularly *Centrosema pubescens*.

PRODUCTIVITY OF THE SPECIES

Herbage Dry-Matter Yield

There is considerable literature showing that *Brachiaria* spp. can give high yields of forage under good climate and management (Table 1). Yields range between 5 and 36 t DM/ha/year depending on soil fertility, moisture and fertilizer application (Bogdan, 1977). There is very little information on the productivity of *Brachiaria* spp. in Tanzania despite the fact that the grass is indigenous to grasslands there. The little information available is based mainly on *Brachiaria brizantha*.

Table 1. Influence of Nitrogen rate and cutting interval on the DM yield (t/ha/yr) of Brachiaria spp.

Grass spp.	Age (days)	Rate of N (kg N/ha) 0	45	56.1	62.5	112.3	125	134.7	168.4	185	224.6	280.7	404.2	449.2	
B. brizantha				10.4		13.2			14.7		15.2	17.4			Appandurai and Arassaratnam (1969) Sri Lanka
B. ruziziensis	30	8.7									14.3			21.0	Vicente-Chandler et al (1972)
	45	11.2									19.6			28.4	Puerto Rico
	60	9.6									21.0			31.0	
	90	16.5									35.6			50.0	
B. brizantha	30	23.7	28.1					30.2					33.6		Sivalingam (1964)
	60	22.1	23.0					27.5					29.0		Sri Lanka
	90	19.6	23.0					27.8					28.3		
B. brizantha	56	2.9			6		8			9.8					Fredricksen and Kategile (1980) Tanzania
B. ruziziensis		6.1									13.9			21.8	Olsen (1972) South America

Without fertilizer application, Frederiksen and Kategile (1980), reported a yield of about 3 t DM/ha on a 10-year-old field (Table 2). On fertilizer application yields were raised to about 10 t DM/ha. Kidunda (unpublished data) reported yields of 9.5 t DM/ha on unfertilized newly established plots. *Brachiaria* spp. generally respond very well to fertilizer application (Tables 2 and 3), and the age of the sward seems to influence both the response and yield. Observations on the 20-year-old swards at Morogoro indicate that very few grass species can compete with *Brachiaria* spp. on persistence; this makes the species especially valuable in grazing lands. Where irrigation facilities are available, yields per annum could also be raised severalfold.

Table 2. The effect of nitrogen application on the yield, nitrogen utilization, CP% and nitrogen recovery rate on *B. brizantha* at Morogoro in Tanzania.

N level kg/ha	Yield tons DM/ha		Response kg DM/kg N		IVOMD		CP % of DM		Nitrogen recovery rate	
	1973	'74	'73	'74	'73	'74	'73	'74	'73	'74
0	2.8	2.9			48	55	5.9	5.5		
62.5	5.8	6.2	48	53	54	54	4.6	5.4	38	50
125	8.9	7.6	49	37	54	59	5.4	7.4	42	55
187.5	9.8	8.2	37	28	53	57	7.6	6.1	48	55

*IVOMD = *In vitro* organic-matter digestibility.
Source: Fredricksen and Kategile (1980).

Table 3. Effect of nitrogen fertilizer application on the annual dry-matter production (t/ha); CP% of DM and yield of CP (t/ha) of *Brachiaria ruziziensis* and *Chloris gayana*.

	Rate of N		application		(kg/ha/year)	
	0	224	440	896	1568	2240
Brachiaria ruziziensis						
DM yield (t/ha)	6.1	13.9	21.8	26.5	25.9	23.5
CP % of DM	6.7	7.7	10.1	13.9	16.3	16.8
CP % yield (t/ha)	0.6	1.2	2.4	3.6	4.1	3.9
Chloris gayana						
DM yield (t/ha)	11.2	20.7	24.5	27.8	26.0	25.4
CP % cf DM	8.5	9.3	11.3	14.3	15.7	15.5
CP yield (t/ha)	1.1	1.9	[illegible].8	3.9	3.9	3.9

Source: Olsen (1982) in Uganda.

Nutritive Value

Although no systematic studies have been carried out to evaluate the nutritive value of *Brachiaria* spp. a number of studies has shown that the species is of high nutritive value. Frederiksen and Kategile (1980) reported about 800 kg CP/ha in the fifth week of regrowth (Table 2) and Nnko, (unpublished data) working on the same plots, which were now 20 years old, reported 400 kg CP/ha at a fertilizer application rate of 105 kg N/ha at eighth week of regrowth. Elsewhere higher yields of CP have been reported with higher N fertilization. In Puerto Rico, Vicente-Chandler *et al.*, (1972), reported yields of 3.5 t of CP/ha at a fertilizer rate of 896 kg N/ha and 60 days cutting intervals for *B. ruziziensis*. The rate of N fertilizer will certainly be dictated by the economics in a particular area, but if comparative studies are to be conducted with other grass species such as *Chloris gayana*, *Brachiaria* spp. is likely to outperform them in this respect.

Brachiaria spp. has been reported to have a fairly high mineral content. Mtengeti (unpublished data), studying mineral status of some pasture species at Morogoro in Tanzania, reported high magnesium content of *B. brizantha* as compared to other pasture species studied. The species was reported to have fairly reasonable contents of other minerals as well (Table 4). Similar trends of mineral contents were reported by Vicente-Chandler (1959) with *B. ruziziensis* in Puerto Rico.

Table 4. Mineral composition of *B. brizantha* at preflowering and flowering stage at Morogoro, Tanzania.

Stage of growth	Ash	Ca	P	Mg	K	Ca:P ratio	Cu	Zn	Mn
		%						ppm	
Pre-flowering	11.20	0.33	0.27	0.24	2.76	1.22	6.9	20.30	63.90
Flowering	10.57	0.33	0.21	0.25	2.88	1.55	3.90	20.44	81.57

Source: Mtengeti (unpublished data).

Although no systematic studies have been carried out at Morogoro to study intake and animal production from *Brachiaria* spp., observations have indicated preference and higher intakes by cattle for *Brachiaria* compared to *Chloris gayana*. In studies carried out in western Tanzania, Kapinga (1986) reported that *Brachiaria* spp. was the second most palatable species (after *Leucaena* spp.) out of eleven species studied.

In countries where *Brachiaria* spp. has been managed well as a forage crop, standard agronomic practices have resulted in very impressive animal performance. In Tanzania, there is a need to carry out identification, selection and improvement particularly on those varieties that set viable seeds and if possible identify varieties for the different ecological conditions. Combinations of *Brachiaria* spp. with different legume species have given impressive results elsewhere (Table 5) and are likely to give the same results in Tanzania. This is worth studying and exploiting for optimal production. The fact that *Brachiaria* spp. has performed extremely well in countries where it has been introduced should act as a catalyst to improve it in its native land and utilise this useful animal feed resource otherwise lying idle.

Table 5. Average stocking rate and cattle liveweight gains on improved pasture.

Pasture	Average stocking rate (beast/ha)	Liveweight gains	
		Per day	Per year
Rhodes + Stylo	3.7	1.5	543
Para + Centro	4.0	1.8	662
Guinea + Centro	4.0	1.7	614
Guinea + Stylo	3.6	1.6	577

Source: Allen and Cowdry (1961).

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EVALUATION OF THE POTENTIAL OF SOME COMMON FORAGE GERMPLASMS IN MAURITIUS

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Abstract

Background information on the climate, livestock production systems, constraints to increased animal production and the role and scope of pasture and cultivated fodders in Mauritius to enable a proper understanding of the problem are highlighted. The results of some recent experiments on the evaluation of selected species of grasses for the different ecological zones are described. Particular emphasis is laid on the need for proper screening methods of pasture species and fodder crops and appropriate management techniques to improve productivity for the benefit of the livestock industry. Proposals for future research orientation are also outlined.

LIVESTOCK AND FODDER DEVELOPMENT

Mauritius spends a considerable amount of money on the import of ruminants. However, during the past years the Government has given priority to development programmes in animal production, with the objectives, *inter alia,* to improve human nutrition, to create employment and to conserve foreign exchange.

Significant constraints to improved animal production in Mauritius are the scarcity of land for fodder production and the low productivity of existing low potential pasture land. Historically, the establishment and management of improved pastures has not been given priority by ruminant owners for various reasons. In recent years, however, the need to consolidate the livestock industries has been appreciated, and this is reflected in the increased interest in pasture improvement. Moreover, the Government is currently setting up fodder units in various regions to provide incentives to small-scale cattle keepers, as well as stabilising the sugar production to about 600,000 tonnes/year so as to release land for food and feed production. A better utilisation of the Crown Lands, *inter alia,* through agroforestry is also being considered.

BASIC FORAGE RESOURCES

The basic feed resources can be classified into two main categories:

1. Grasses, legumes and tree fodder.
2. Crop residues, wastes from animal production and residues from the processing of food for human consumption.

The forage/fodder species currently grown depend, *inter alia,* on the ecological conditions and the system of livestock management adopted. According to Naidu (1973), the most commonly used species in order of importance for the cut-and-carry system from sources other than pasture in the three agro-climatic regions of the island are shown in Table 1.

Table 1. Fodder species of importance in the various ecological zones.

Ecological zone	Fodder species in order of importance
Subhumid	*Stenotaphrum dimidiatum* *Cynodon dactylon* *Panicum maximum* *Leucaena leucocephala*
Humid	*Pennisetum purpureum* *Stenotaphrum dimidiatum* *Paspalum paniculatum* *Leucaena leucocephala*
Superhumid	*Ischaemum aristatum* *Pennisetum purpureum* *Passiflora suberosa*

On the other hand, in the drier regions, where forage exploitation is to a large extent through grazing, the natural pastures exist mainly under the plantations of *Casuarina equisetifolia*. The pastures grazed consist essentially of *Stenotaphrum dimidiatum, Cynodon dactylon* and *Panicum maximum*. New species have been introduced of which *Cynodon plectostachyus* and *Leucaena leucocephala* have been the most promising.

CULTIVATED FORAGES

In order to increase animal production in Mauritius, the government is presently experimenting with the setting up of fodder plantations in selected villages. Forages are also increasingly being cultivated on government stations and to a lesser extent on private land; the main species involved are *Pennisetum purpureum, Leucaena leucocephala, Setaria sphacelata* and *Cynodon plectostachyus*.

FORAGE EVALUATION STUDIES

Primarily due to the marginal role of pastures in meeting the feed requirements of animals, the evaluation of forage in Mauritius has been sporadic with little coordination and lack of continuity. However, more systematic studies in the evaluation of selected forages are presently being carried out. The main research activities in respect of past evaluation of common forages are highlighted to indicate the scope of past and present activities. Unfortunately, the evaluation has not been thorough; most of the data relate to agronomic and to a lesser extent some nutritive value criteria.

Grasses

The need to exploit the potential of grasslands as an important resource for extensive low-cost feeding (grazing) as well as for fodder cultivation used in the cut-and-carry system is increasingly being felt. Serious efforts to identify high yielding and high quality grasses for the different ecological zones, to assess the effects of fertilizer application and to assess the effect of cutting interval and cutting height have been made since the early 70s. These studies have been undertaken mainly by the FAO Milk and Meat Project and the Ministry of Agriculture and have concentrated mainly on the collection of agronomic data.

The productivity of eight selected grasses have been evaluated in two ecological zones (subhumid and superhumid) and the results are presented in Tables 2 and 3.

Data for the other two species of grasses namely *Cenchrus ciliaris* and *Chloris gayana* were not included in Table 2 due to abnormally low productivity and poor persistency. The parameters given for 1978 were consistently superior to those 1974; and although *Setaria sphacelata* outyielded the other species in some respects, the crude protein yield was not superior. Other studies conducted in the superhumid zone confirms the superiority of *Setaria sphacelata* (Jhundoo, 1986) in terms of fresh and dry matter production. However, bearing in mind the fact that protein is probably the most critical nutrient in Mauritian forages, this does not necessarily imply that *Setaria sphacelata* is the most suitable feedstuff.

Table 2. Production parameters of 6 species of grasses in superhumid zone for 1974 and 1978 (2 cuts).

Grass species	Fresh matter $t.ha^{-1}$ yr^{-1}		Dry matter $t.ha^{-1}$ yr^{-1}		Crude Protein $t.ha^{-1}$ yr^{-1}		Crude fibre $t.ha^{-1}$ yr^{-1}	
	1974*	1978**	1974	1978	1974	1978	1974	1978
Setaria sphacelata	96.2	120.2	27.4	34.2	1.4	1.8	6.3	7.9
Tripsacum lexum	77.5	96.9	14.8	18.5	1.4	1.8	4.8	6.0
Brachiaria ruziziensis	73.8	92.2	17.2	21.5	1.5	1.9	5.5	6.9
Brachiaria brizantha	72.2	90.2	15.0	18.7	1.4	1.8	4.6	5.7
Pennisetum purpureum	64.5	80.6	12.2	15.3	1.2	1.5	3.9	4.9
Panicum maximum	57.2	71.5	13.8	17.3	1.4	1.7	4.5	5.6
S.E. of means	±3.5	±3.5	±3.5	±3.4	±0.4	±0.4	±1.2	±1.2

* 1974 : 5 months cutting interval.
**1978 : 4 months cutting interval.
Source: Naidu (1980, 1982).

The results of experiments carried out in the subhumid zone are given in Table 3. Generally it can be concluded that *Pennisetum purpureum* is the most vigorous, persistent and highly adapted species, and thus can be safely recommended for the subhumid regions especially for zero-grazing. Productivity data for the five species for 1976 have been omitted due to their poor performance probably resulting from unfavourable climatic conditions.

Table 3. Production parameters of 8 species of grasses in subhumid zone for 1976 and 1978 (3 cuts).

Grass species	Fresh matter $t.ha^{-1}\ yr^{-1}$		Dry matter $t.ha^{-1}\ yr^{-1}$		Crude Protein $t.ha^{-1}\ yr^{-1}$		Crude fibre $t.ha^{-1}\ yr^{-1}$	
	1976*	1978**	1976	1978	1976	1978	1976	1978
Pennisetum purpureum	129.8	162.3	28.0	35.0	8.1	10.1	3.5	4.4
Centrus ciliaris	-	60.9	-	24.0	-	8.4	-	4.2
Chloris gayana	-	60.1	-	21.8	-	6.4	-	4.3
Panicum maximum	-	79.8	-	26.9	-	8.7	-	4.1
Brachiaria brizantha	54.1	72.2	21.4	29.2	6.8	9.3	3.6	3.8
Brachiaria ruziziensis	43.3	77.3	17.5	30.6	5.6	9.7	2.3	5.2
Digitaria decumbens	-	59.1	-	20.3	-	7.4	-	2.7
Setaria sphacelata	-	86.7	-	22.2	-	7.2	-	3.7
S.E. of means	±3.5	±3.3	±3.2	±3.35	±0.4	±0.41	±1.2	±1.2

Source: Naidu (1980, 1982).

On the other hand, assessment of the potential of *Stenotaphrum dimidiatum*, the dominant species in the shaded and open pasture of the drier regions and *Ischaemum aristatum*, a common species of the superhumid zones have been virtually neglected. Published data of Blair and Peerun (1970) on the potential of these two forages, based on five cuts over a ten-month period on the subhumid site at Wolmar show the superiority of *Stenotaphrum dimidiatum*, especially in respect of the crude protein content and yield (Table 4).

Table 4. **Dry-matter and protein yield of** *Stenotaphrum dimidiatum* **and** *Ischaemum aristatum.*

Species	Dry matter $t.ha^{-1}$	Crude protein % dry matter	Crude protein $t.ha^{-1}$
Ischaemum aristatum	17.56	10.6	1.64
Stenotaphrum dimidiatum	20.18	18.5	2.99

The production from *Stenotaphrum dimidiatum* is generally much lower in the wet areas than *Ischaemum aristatum.* An advantage of *Stenotaphrum dimidiatum* is its persistently high crude protein content at various cutting intervals (Blair and Peerun, 1970) (Table 5). Increasing the cutting interval from two to twelve weeks also increased productivity.

Table 5. **Production and cutting interval of** *Stenotaphrum dimidiatum.*

Cutting interval (weeks)	Fresh weight $t.ha^{-1}$	Dry weight $t.ha^{-1}$	Crude protein % of DM	Crude protein $t.ha^{-1}$
2	12.50	1.87	11.6	0.22
4	21.25	2.76	17.6	0.49
6	30.25	4.39	13.3	0.48
8	38.75	5.43	15.3	0.83
10	40.00	5.48	15.7	0.86
12	47.50	6.41	14.8	0.95

Data on fertilizer responses of the grasses are only fragmentary. The need for properly fertilizing fodder plantations and pastures not only with nitrogen, but also with potassium, phosphorus and sulphur is not fully realised. As a consequence there is a decrease in production in subsequent cropping of these fodders.

The effects of different levels of nitrogen fertilizer on the yield of three species of grass has been reported by Heerasing (1986). His experiments showed that increasing levels of nitrogen application positively influenced yield in *Pennisetum clandestinum* and *Brachiaria brizantha* only (Table 6). However, the results of an identical trial conducted earlier by the same author did not reveal any improvement in yield of the three grasses.

Table 6. Effect of fertilizer response of three species of grass.

Rate of N application (kg/ha)	Yield (k/ha, 3 cuts)		
	Setaria sphacelata	*Pennisetum clandestinum*	*Brachiaria brizantha*
0	135	65	70
10	121	69	92
15	130	63	87
20	130	82	94

Legumes

Besides evaluation studies on grasses, the potential of legumes, mainly *Leucaena leucocephala*, has been assessed since the early 70s. It is naturalised legume and therefore offers considerable potential for exploitation not only as fodder but also in agroforestry programmes, alley farming, hedges and erosion control. Its major advantage is the high crude protein level, a nutrient which is deficient in tropical forages.

A series of agronomic trials on *Leucaena leucocephala* have been conducted by Osman (1979), Rojoa (1982) and Heerasing (1984) to assess the role of various management practices on the productivity of this legume. Notably inter-row spacing of the plants have been shown to exert an effect on yield (Osman, 1979; Naidu, 1980; Rojoa, 1982; Heerasing, 1984,). Most of the authors have come to the conclusion that an inter-row spacing of between 90-100 cm yielded the best results. Only Osman (1979) found the optimum spacing to be 180 cm. Experiments on the effect of cutting height on yields were also undertaken (Osman, 1979) who in a 40-month period noted that the best cutting height was 75 to 150 cm, while Heerasing reported the optimum cutting height to be 37.5 cm.

Other conclusions reached by Osman (1979) are:

1. Cutting frequency has an important bearing on productivity. A frequency of cutting of 90 to 150 days (depending on season) was the most appropriate.

2. When properly inoculated with suitable *Rhizobium* strains, fertilization is not needed.

3. Overgrazing by animals, especially the goat and the deer is detrimental to *Leucaena* productivity.

4. A productivity of 13 tonnes/ha^{-1}/yr^{-1} dry matter and a protein yield of 3.5 t/ha^{-1}/yr^{-1} have been obtained without fertilization and irrigation in the humid zone.

Various nutritive value criteria have been assessed. Dry-matter digestibility and various feeding trials have been undertaken during the past decade. Generally, the recorded data demonstrate that *Leucaena leucocephala* exerts positive effects on animal performance when used as a supplementary source of protein due to its ability to provide appreciable by-pass protein which is important especially for high performance animals feeding on low-quality fibrous feeds. Providing high levels of *Leucaena leucocephala* in the diet is not only economically unsound but influences certain parameters, *inter alia*, a reduction of milk fat in lactating animals (Mardamootoo, personal communication), depression in animal performance and the possibility of intoxication.

The problem of leucaena toxicity, fortunately is a regional one. In some countries, including Mauritius, it is well established that there exist rumen micro-organisms capable of degrading the toxic goitrogenic metabolite of mimosine (Jones, 1981). Immunity against leucaena toxicity can easily be imparted to animals via infusion of rumen fluid from immune animals or suitable inoculum. This no doubt offers scope for increased utilisation of this highly productive and persistent legume.

Other legumes which warrant further investigation to improve grassland quality (Osman, 1979) are:

1. For the very wet regions:

   Stylosanthes guianensis
   Macroptilium atropurpureum
   Neonotonia wightii
   Vigna marina

2. For dry regions: *Stylosanthes humilis*.

The establishment method advocated is that of oversowing the existing grass cover with the seed of these legumes.

Sugarcane

Another fodder plant of potential economic importance is sugarcane (*Saccharum officinarum L.*). The interest in the sugarcane plant lies primarily in its high potential to trap the sun's energy, which is in general superior to other commonly grown crops, because of its perenniality and its value as a dry season feed. Biomass production of up to 64 tonnes dry matter per hectare per annum has been recorded (Bachofen *et al*, 1981). The use of sugarcane as a feed for ruminants is particularly appropriate in times of low sugar prices, which makes the utilisation of land through production of sugarcane for conversion through animals an interesting proposition. The potential of the whole sugarcane plant for feeding animals has been given considerable research inputs in various sugar-producing countries since the early 1970s (Jotee, 1984).

An experiment was carried out in Mauritius to study the effect of monthly cutting intervals from four to twelve months (Rajkomar, 1977). The results reproduced in Table 7 show a slight increase in dry-matter yield but an appreciable decrease in protein yield with time. Further studies on the effect of

Table 7. Effect of cutting interval on yield of sugarcane.

Cutting interval (months)	Fresh matter t/ha^{-1}	Dry matter t/ha^{-1}	% Crude protein on DM basis	Crude fibre t/ha^{-1}
4	149.3	35.8	3.8	8.51
5	135.2	27.4	4.8	7.46
6	145.8	37.5	4.2	8.85
7	129.2	25.2	5.8	7.74
8	141.5	34.5	4.1	8.06
9	180.3	32.5	3.9	8.23
10	177.1	40.5	3.0	9.61
11	164.4	40.9	2.7	7.88
12	140.3	36.0	2.1	6.98

fertilizer application of 100, 200 and 300 kg nitrogen per hectare (Rajkomar, 1977) did not reveal any positive response to increased nitrogen fertilization on the overall yield.

Unlike most green forages in the tropics, sugarcane is characterised by an increase in organic-matter digestibility from six months to 24 months after planting (Kung and Stanley, 1982), and therefore can serve as a useful fodderbank during the dry season in certain countries. However, due to a decline in protein content with time, proper supplementation with by-pass protein in particular is desirable for satisfactory performance.

CONCLUSIONS

The success of any livestock development programme in Mauritius will partly depend on the research input in pasture and fodder crop production. Hitherto the resource persons involved in the agronomic studies, chemical analyses and in the animal production sector have always worked in isolation. This has resulted in a lack of coordination which has hampered development; therefore, a multi-disciplinary approach is essential, as well as the need for standardisation of methodology and the use of maximum criteria for assessment. However, before any new fodder and pasture improvement plans are made, it is of utmost importance to make a thorough assessment of existing data on available feedstuffs and future requirements.

The integration of fodder production into forest plantations has a good potential for the further development of the livestock sector. Therefore in the drier areas, where the stomoxys fly is not a problem, grazing by cattle/deer needs to be promoted. In the other areas, emphasis must be laid on the zero-grazing system mainly for the smallholders.

Future research programmes to increase forage production and efficiency of animal production should, *inter alia,* include:

1. More in-depth studies to assess the various management techniques used, viz. levels of cutting with respect to frequency and ageing, and fertilizer responses profiles for the main agro-climatic zones.

2. Further investigation of naturalised/indigenous and exotic genotypes in relation to their persistency in long-term experiments.

3. Concurrent experiments to assess the nutritive value of various forage and mixtures through digestibility studies and feeding/grazing trials.

4. Further evaluation of other sources of feeds, namely the sugarcane tops, maize stover and cobs and other crop residues to enhance forage availability and hence production.

5. Establishment of on-farm demonstrations to highlight the benefits of improved fodder production techniques to smallholders.

6. Provision of more training facilities, research inputs and other logistic support.

7. Economic analyses of the various production systems.

Implementation of these proposals, no doubt, will contribute to improving the scope and efficiency of animal production in Mauritius.

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A REVIEW OF FORAGE GERMPLASM INTRODUCTION AND EVALUATION IN UGANDA

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ABSTRACT

Forage germplasm introduction and evaluation work in Uganda has been reviewed. Many species have been evaluated by different workers in different parts of the country. This has been in terms of their establishment, persistence and production characteristics, fertilization and yields, defoliation, chemical composition and nutritive values, animal productivity and their seeding abilities. From these studies, the Ministry of Agriculture has demarcated Uganda into six zones with recommendations of various pasture species for each zone. Most of the grass species evaluated and recommended are indegenous to Uganda, while nearly all the legume species are exotic. Availability of planting seed has been observed as the major hindrance to pasture development programmes in the country.

INTRODUCTION

Uganda is one of the East African countries crossed by the Equator, and lying between latitude 4°12'N and 1°29'S and longitude 29°34'E and 35°E. It is bordered by the Sudan in the north, Kenya in the east, Tanzania and Rwanda in the south and Zaire in the west. It covers a total area of 235,886 sq. km.

The climate is good, with a mean annual rainfall varying from 510 mm in the North-Eastern parts of Karamoja to 2160 mm or more in the Sesse Islands in Lake Victoria. The rainfall is bi-modal with the first peak being in March-May (first rains) and the second in September-November (second rains) with dry periods in between the peaks. Further north the two seasons tend to coalesce into one rainy season of about five months centred around July and one long dry hot season. A mean monthly maximum temperature exceeding 37.8°C has been recorded in some parts of the country with a seasonal variation barely above 6°C. A figure of 10°C for mean monthly minimum temperatures has also been obtained with a seasonal variation of just about 3°C.

Generally most soils are able to support some form of agriculture. Those soils with high productivity include:

1. those associated with volcanic activities,

2. those clays formed from parent material derived partly or wholly from basic amphibolite rocks,

3. those deep, red or brown, loam or clay loam, pediment soils,

4. deep sedimentary soils.

The above four groups are well represented all over the country and have been cultivated extensively. There are also those soils with low to nil productivity, which are shallow or very sandy or sometimes with a lot of gravel. This group also includes those montane soils on the slopes of mountains. These are mostly in the north with localised patches and pockets in the rest of the country.

Vegetation varies from rain forests to savanna and grassland with a small patch of bushland and thicket in the extreme northeastern part of the country in Karamoja.

Agriculture is the backbone of Uganda's economy, engaging the majority of the population and currently accounting for about 95% of all foreign exchange earnings. Crop husbandry plays the leading role in the overall farming system and is poorly integrated with animal husbandry. Livestock are an important factor in the ordinary life of the majority of Ugandans. Their values to the owners range from wholly economical to social/prestigious uses in marriages and other cultural ceremonies and as security against shortcomings. The productivity of these herds is, however, very low. The livestock population density is greatest in the northern and northeastern parts of the country. These areas also tend to have low rainfall and can be classified as natural grasslands or rangelands. According to the 1979 statistics of the Ministry of Animal Industry and Fisheries, Uganda had 5,053,510 cattle, 2,453,528 goats and 962,315 sheep.

LOCATION OF PASTURE RESEARCH IN UGANDA

A number of institutions are involved in pasture research in Uganda. These stem from two different parent ministries, namely the Ministry of Agriculture and the Ministry of Animal Industry and Fisheries (Veterinary Department). Although pasture work can be traced way back to the turn of this century, it was not until 1920 that a proper experimental station was established.

Currently three research institutions are engaged in pasture research in the country in addition to the Faculty of Agriculture of Makerere University. These are:

1. Serere Research Station - established in 1920 in the East to carry out experimental work in the so-called "short-grass areas" i.e. in the eastern and northern parts of the country. This belongs to the Department of Agriculture and carries out research on crops including pastures and some animal work.

2. Kawanda Research Station - about 50 km north of Kampala was established in 1937 in the "tall or elephant grass areas". It belongs to the Department of Agriculture and it is the seat of crop research in the country but with some animal production work going on.

3. Animal Health Research Centre (AHRC) - situated south of Kampala belongs to the Department of Veterinary Services and

Animal Industry. It carries out research and diagnostic services in both animal health and production.

There are, however, some smaller agricultural research stations and agricultural colleges which at some stage have been involved in pasture work. These include Namulonge Research Station, Bukalasa Agricultural College and Arapai Agricultural College, all three belonging to the Ministry of Agriculture. Because of the many institutions involved, which belong to different parent ministries, there arises the problem of coordination of research efforts to avoid duplication. Although Uganda's third Five-Year Development Plan 1971/72-1975/76 stated that "In order to avoid duplication and to effect a better integration of efforts, in future all Government research on livestock and pasture will be sponsored and administered by the Ministry of Animal Industry," this has not fully been implemented.

HISTORICAL HIGHLIGHTS OF PASTURE RESEARCH PRIOR TO 1960

A brief chronological listing of the highlights of pasture research findings in Uganda up to 1960 has been given by Henderlong (1973) as follows:

1906 Introduction of legume species primarily for vegetative cover and soil conservation.

1925 A collection of pasture grasses started by Maitland near Kampala.

1930 Selected species from the 1925 planting were established in larger plots at Bukalasa for general observations on grazing and feeding.

1931 Grass collections were started at Ngetta and later at Serere.

1932 Continuous cultivation of arable crops even with green manures was shown at Serere to result in decreased crop yields when compared to crop yields under shifting cultivation.

1933 All governmental farms in Uganda changed their crop rotations to include a two- to four-year planted grass rest (ley) phase. This policy gave the first real impetus to research investigations with the local grasses.

1945 *Stylosanthes gracilis* was introduced in Uganda from Australia by Thomas (1966) and planted at Kawanda and later at Serere.

1948 *Chloris gayana* was recommended as the best overall grass species for the grazed temporary ley throughout most of Uganda. In some areas, elephant grass (*Pennisetum purpureum*) was also commonly used for the temporary ley phase, but it proved difficult to eradicate from cropland.

It required vegetative planting, and it was better adapted as a fodder crop than for direct grazing.

1954 Detailed systematic work on grass and grass-legume mixtures was initiated at Serere by Horrell (1958).

1956-1958 Introduction of legume species for the "forest area" was initiated at Kawanda in addition to the earlier grass museum and introductions at Kawanda by Thomas (1966). These initial studies included over 100 different grass species, of both temperate and tropical origins, and approximately 60 different tropical and temperate legumes.

EVALUATION STUDIES OF PASTURE SPECIES

Much of the earlier detailed investigative work was done mainly on grasses. Various texts were published on these grasses. Initially they were investigated for the rest period after arable cropping, and their importance as a source of grazing or fodder was then subsidiary. The effects of the animals on soil fertility were unclear until it was later shown that grazing did not reduce yields of subsequent crops (Kerrham, 1947).

The introduction of exotic animals after 1960 was an impetus to extensive grassland improvement. Evaluation of both indigenous and exotic pasture species was initiated as a result of this development. These have, over the years been evaluated in terms of management studies on establishment, persistence and production fertilization and yields and defoliation. Evaluation further concerned itself with chemical composition and nutritive values, animal productivity and seed production.

Establishment, Persistence and Production

Horrell (1958, 1963) gives an account of a wide range of grasses and legumes studied at Serere in nursery plots to determine their suitability for leys in eastern and northern Uganda. He pays special attention to persistence, production, habit, seeding ability and to a lesser extent palatability. The origins of the species in question are also given. From such studies, he was able to recommend the following species for use in eastern and northern Uganda.

Grasses:

Chloris gayana)	
Cenchrus ciliaris)	for leys
Cynodon plectostachyus)	
Hyparrhenia rufa)	
Pennisetum purpureum)	for dry season
Setaria spp.)	supplementary grazing
Paspalum n tatum)	
Cynodon dactylon)	for lawns

Legumes: The most successfully adapted legumes under these conditions included:

Stylosanthes gracilis, *Calopogonium orthocarpum*, *Centrosema pubescens*, *Desmodium* spp., *Pueraria phaseoloides*, *Glycine javanica* (now *Neonotonia wightii*).

All of the above except *Neonotonia wightii* were exotic to Uganda. The study demonstrated the ability of a number of tropical legumes to grow vigorously and reproduce in this environment. A good growth of *Stylosanthes gracilis* with a crude protein content of up to 24% has been achieved at Animal Health Research Centre (AHRC Entebbe, unpublished data). *Chloris gayana* has also been successfully established under a silage crop cover of sorghum at Entebbe while *Melinis minutiflora* was unable to establish (Harker, 1954). *Pennisetum clandestinum* was found to grow well in pot experiments at AHRC, Entebbe (unpublished). Other pasture species have been tried in different environments in Uganda, but the reports are difficult to come by.

Fertilization and Yields

The use of fertilizers was considered important in pasture work in Uganda. Nitrogen fertilization was established to be essential for good production of pure grass swards or leys (Horrell and Bredon, 1963; Horrell and Tiley, 1970; Olsen, 1972). It was found that production of grass species falls sharply in the second and third years from planting but that yields could be maintained at a steady level by application of N or by the inclusion of a successful legume such as *Desmodium intortum*.

Phosphorus or superphosphate was proved valuable for the establishment of legumes (Stobbs, 1969a; Olsen and Moe, 1971). They reported that liming was useful for the persistence of lucerne and its nodulation but showed no general effects on the establishment, persistence, production or nodulation of either *Desmodium* or *Stylosanthes*.

Responses of *Hyparrhenia rufa*, *Panicum maximum*, *Stylosanthes guianensis*, *Centrosema pubescens* and *Macroptilium atropurpureum* to phosphorus, sulphur and potassium in eastern Uganda were investigated by Wendt (1970). All the species responded to P and S to levels of application of about 70 kg/ha of P and 20-40 kg/ha of S giving yield increases of 40-100%.

Much work has been done to evaluate the compatibility of various grasses and legumes when planted in mixtures. Results of Olsen and Tiharuhondi (1972) discouraged the sowing of *Desmodium intortum* with *Chloris gayana*. Both *D. intortum* and *Medicago sativa* made good association with *Panicum maximum* and *Setaria anceps* (now *sphacelata*).

Defoliation

Literature on this aspect of forage evaluation is scanty. It appears that few studies on this aspect were undertaken. Horrell and Bredon (1963) working on *Panicum maximum* at Serere reported highest DM yields at cutting intervals of nine weeks while best yields of CP were obtained at cutting intervals of between six and nine weeks. Although there are no reports on legume defoliation studies in Uganda, Henderlong (1973) observed that the rate of regrowth of lucerne after defoliation was considerably more rapid than for any of the adapted tropical legumes.

Chemical Composition and Nutritive Values

A number of workers evaluated various species for their chemical composition and nutritive values. Some of this work was carried out in different ecological zones. Species were analysed for crude protein, crude fat, crude fibre, ash and silica contents and for the various mineral element contents. This was done on both planted and rangeland pastures but mostly on grasses. The various grass species analysed in greater details in this respect were *Pennisetum purpureum, Themeda triandra, Panicum maximum, Chloris gayana, Cynodon dactylon, Digitaria* spp., *Hyparrhenia* spp., *Melinis minutiflora, Setaria* spp. and many other range species.

Pennisetum purpureum, an indigenous grass of Uganda, has been found to be of very high value as cattle feed with a CP% content ranging between 9.2-20.5 and CF% of 29.3-37.7 (Marshall and Bredon, 1963). It is used both as a pasture plant as well as fodder crop. Although pure pasture leys of individual herbage species are unusual in Uganda, *P. purpureum* and *Setaria sphacelata* have proved to be among the most productive pasture grasses and have been proposed for commercial use (Morrison, 1971).

Nutritive value assessments of pastures and forages have been reported by Juko and Bredon (1961), Bredon *et al.*, (1963), Musangi (1965) and many others. The nutritional value of some common cattle browse and fodder plants of Karamoja, northeastern Uganda, has also been investigated by Wilson and Bredon (1963).

Due to the role played by rangeland for the grazing animal, several workers have attempted to evaluate the quality of range pastures in different parts of the country. Reports of Reid *et al.* (1973) indicate that natural grasslands in Uganda had lower digestibilities than the planted species. But the higher digestibilities in planted species declined more rapidly with maturity than the natural grasslands. They also reported that *Brachiaria* generally exhibited one of the highest levels of *in vitro* digestibilities among the species evaluated which agrees with the *in vitro* data of Soneji *et al.* (1971) which indicated higher digestibilities for *Brachiaria ruziziensis* than either *Chloris gayana* or *Setaria sphacelata*. Legume species on the other hand generally had lower digestibilities than the grasses in the early stages of growth, but the decline in legume digestibility was considerably less marked than for the planted grasses (Reid *et al.*, 1973).

Digestibility trials and chemical analyses of indigenous grasses at AHRC indicated adequate starch equivalent values for both maintenance and an element of production throughout the year while protein was frequently limited (Marshall *et al.*, 1961; Bredon and Torrell, 1962; Bredon and Marshall, 1962). Proximate analyses on rangeland grasses of western Uganda indicated lower CP values for *Themeda triandra* (4.14%) and *Hyparrhenia filipendula* (4.41%) compared to *Brachiaria* spp. (6.49-7.64%), *Chloris gayana* (5.96%), *Panicum maximum* (6.61%) and *Cynodon dactylon* (8.27%).

Various workers have analysed various pasture plants for their mineral contents in different localities. Minerals analysed for include: N, Na, K, Mg, P, Mn, Cu, Zn, Co, Mb, S, Sn. Investigations on the mineral status of the commonly used grasses on farms in Buganda and Busoga and also in western Uganda in the Queen Elizabeth National Park indicated adequate amounts of N, K, Mg, Mn, Cu, Mb and S while levels of Na, Ca, P, Zn and Co were marginal or deficient in many grasses thus requiring supplementation (Long *et al.*, 1969; Long *et al.*, 1970).

Mean mineral composition (%) of some Uganda grasses as reviewed by Harrington and Pratchett (1973) are given in Table 1.

Table 1. Mean mineral composition (%) of some Uganda grasses.

	Sodium	Potassium	Magnesium	Calcium	Phosphorus
Themeda triandra	0.034	0.50	0.09	0.31	0.11
Chloris gayana	0.041	1.17	0.15	0.29	0.22
Setaria sphacelata	0.046	1.82	0.13	0.41	0.26
Brachiaria playtynota	0.034	1.19	0.19	0.40	0.17
B. brizantha	0.045	1.16	0.17	0.39	0.21

Ssekaalo (1972) working on eastern Uganda pastures, concluded that grass species generally contained less cobalt than legumes. Grasses had little difference in their cobalt content and so did the legumes with the exception of *Macroptilium atropurpureum*. The cobalt content was enough to meet animal requirements except where *Pennisetum purpureum* was the main fodder. Selenium status of pastures in Uganda has also been analysed by Long and Marshall (1973). The better quality grasses, judged on the bases of CP content and DM digestibilities such as *Brachiaria* spp., *Cynodon dactylon, Panicum maximum* and *Setaria aequalis* tended to have satisfactory mineral contents while the more typical savanna type grasses, *Hyparrhenia filipendula* and *Themeda triandra* were generally low in essential minerals (Long *et al.*, 1969).

Animal Productivity

Forage evaluation through livestock productivity has been studied at Serere by Stobbs (1969c) and Otim (1973). Higher values in terms of animal production have been obtained when various legumes have been included in the grazing systems. Stobbs (1969b) investigated *Stylosanthes gracilis* and *Centrosema pubescens* as mixtures, top dressed with single superphosphate fertilizer. *Stylosanthes gracilis* because of its small hairy leaves and woody stems generally had low intake while *Calopogonium mucunoides*, one of the best legumes tested at

Serere, was completely unacceptable to the animal (Otim, 1973). *Paspalum notatum* was able to maintain excellent beef production at Namulonge Station, indicating its relatively high digestibility.

Seed Production

The availability of planting seed is a major hindrance to pasture development efforts in Uganda. Preliminary evaluations of the various species for seed production have indicated that most of the various recommended species were able to produce seed. Emphasis has been put on legume seed production. *Stylosanthes, Neonotonia, Centrosema* and *Macroptilium* spp. have produced reasonable seed yields at Serere while *Desmodium* and *Medicago* spp. were not as successful (Wendt, 1970).

RECOMMENDED PASTURE SPECIES

General planted pasture zones have been established with recommended species for each zone, as follows:

ZONE 1: Pennisetum purpureum
(Hoima, N. Toro, Mubende, Mpigi, S. Busoga, E. Masaka)

Grasses: *Pennisetum purpureum*
Panicum maximum
Chloris gayana
Brachiaria ruziziensis
Setaria sphacelata

Legumes: *Desmodium intortum*
Desmodium uncinatum
Medicago sativa
Neonotonia wightii
Stylosanthes gracilis (on poor or stony soils)
Centrosema pubescens
Macroptilium atropurpureum

ZONE 2: Moist western areas
(S.E. Toro, N. and W. Ankole, N. Kigezi, S. West Nile)

Grasses: *Chloris gayana*
Setaria sphacelata
Brachiaria ruziziensis
Melinis minutiflora

Legumes: *Desmodium intortum*
Desmodium uncinatum
Macroptilium atropurpureum
Trifolium spp. (above 1700 metres).

ZONE 3: Highland areas
(S. Kigezi, W. Toro, S. Sebei, E. Bugisu)

Grasses: *Chloris gayana*
Setaria sphacelata
Pennisetum clandestinum
Pennisetum purpureum (for fodder)
Melinis minutiflora
Legumes: *Desmodium intortum*
Desmodium uncinatum (lower altitudes)
Trifolium spp.
Medicago sativa

ZONE 4: Hyparrhenia spp.
(West Nile, Madi-Moyo, Acholi, W. Karamoja, Lango, Teso, N. Sebei, W. Bugisu, Tororo, N. Busoga, Luwero, N.E. Mubende, Masindi, N. Toro)

Grasses: *Panicum maximum*
Hyparrhenia rufa
Chloris gayana
Setaria sphacelata
Brachiaria spp.
Cynodon dactylon

ZONE 5: Themeda triandra
(Central Karamoja, S.W. Toro, E. and N.W. Ankole, N.W. Masaka, S.W. Mpigi, S. Mubende)

Grasses: *Chloris gayana*
Cenchrus ciliaris

Legumes: *Stylosanthes gracilis*
Macroptilium atropurpureum

ZONE 6: Not suitable for leys
(E. Karamoja, Muntain summits)

DISCUSSION AND CONCLUSION

The climate of Uganda is generally considered as being good. There is adequate well distributed rainfall in most parts of the country. The soils are generally good. Hence many crops including pasture are capable of growing in various parts of the country.

Pasture work in Uganda can be traced as far back as the beginning of this century. The initial aim of pasture establishment was to assist in the regeneration of soil fertility of continuously farmed land for the subsequent crops. The value of grazing these pastures was by then unknown as it was believed that this would interfere with the normal process of soil regeneration and hence affect the yield of the following crops.

A journey across most parts of Uganda will reveal the availability of ample amounts of unutilised herbage. These natural pastures can easily be grazed by livestock. The availability of such herbage has not been an inducement to pasture improvement schemes involving farmers. Increasing pressure on the land as already observed in parts like Kigezi in the southwest, Mbale in the east and a few other places will require efficient management of the resources so as to support the increasing human and animal populations. The provision of better adapted, more nutritious forages for livestock will go a long way in improving the productivity of national herds. Uganda is rich in its plant genetic resources of forage potential which are as yet to be exploited. Many indigenous grass species have been evaluated for their forage value and many have been recommended for various parts of the country. Indigenous legumes on the other hand have not been exploited. Only *Neonotonia wightii* has been studied in detail and recommended as a useful pasture plant. The rest of the legumes evaluated and recommended are exotic, most of them being of South American origin. They have been evaluated in terms of their establishment and persistence, chemical composition and nutritive values, fertilization and yields, defoliation and seed production. Livestock productivity from such pasture has also been evaluated. Some of these trials have, however, been limited to the research stations only, taking into account the two broad areas i.e. "long grass areas" and "short grass areas". Extensive multilocational trials of various species have not been effected and this could be the cause of poor performance in some areas. This should therefore be carried out.

One of the current problems limiting forage evaluation studies and requiring attention is the lack of planting seed. Many of the species tried have been found to seed well. In the past Kawanda and Serere have produced limited quantities of pasture seed, but this has since stopped. Currently, pasture seed must be imported from abroad if required. For researchers needing small quantities of seed, the solution has been solved by ILCA's FLAG programme which has gratefully supplied small quantities of seed for local multiplication purposes.

Despite the important achievements in pasture research in Uganda, one wonders to what extent this has contributed to the overall livestock productivity in the country. The majority of livestock owners are small peasant farmers who graze their herds on communal land. These have obviously gained very little, and the idea of pasture improvement could as well as be a myth to them. There is lacking an integrated package which can be presented to farmers in different parts of Uganda so as to revolutionise their agriculture and enable them to increase their productivity and incomes. Many factors obviously contribute to the lack of an adequate and acceptable technology package of improvements for farmers which include traditional beliefs of large livestock numbers rather than productivity, land tenure systems, tendency to divorce animal from crop husbandry, lack of coordination between research and extension, and lack of incentives and proper training for both research and extension agents. There is still a need for integrated research into systems of farming. Only a few progressive farmers and government-owned livestock enterprises have gained from the results obtained through research. With increasing population pressure on the land and hence reduction in communal grazing lands, it is likely that alternative methods of feeding and improvements will be sought by the majority of livestock owners, but this must be coupled with a good supply of planting seed to farmers.

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FORAGE DRY-MATTER PRODUCTIVITY VARIATION OF *PANICUM* AND *CYNODON* ECOTYPES IN MALAWI

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Abstract

Both Panicum maximum *and* Cynodon nlemfuensis *strains have great variability in forage dry-matter productivity and responsiveness to nitrogen fertilizer application. This variability has been demonstrated and it warrants a wide selection potential for new strains to replace old cultivars in these two species.*

INTRODUCTION

In recent years many developing countries including Malawi have realised the importance of local forage plant genetic resources. However, the lack of funds to facilitate wide-scale collection and detailed evaluation of the local germplasm has limited exploitation of these local forage plant genetic resources. Instead, imports of both legumes and grasses have been done from Australia and other countries. Most of the imported materials are, however, locally represented. To minimise expenses on importations of seed, it was found necessary to critically look at local ecotypes to come up with some cultivars for different ecological niches. The evaluation work is limited by a lack of experience in local forage exploration and by availability of funds. Forage productivity evaluation is therefore limited to a few most promising germplasms namely *Neonotonia*, *Panicum* and *Cynodon* species. Only the work on *Panicum maximum* and *Cynodon nlemfuensis* is reported here.

MATERIALS AND METHODS

During the 1980/81 growing season, a forage plant collection trip was made to some parts of the central and northern regions. The target areas were chosen on the basis of climate and topography hence, seasonally waterlogged valleys (dambos), river courses and the eastern escarpments of the highland zones. Dambo and river courses were chosen to give an indication of forage species whose seed originally came from the inaccessible hills and valleys beyond the escarpments. Collections were made along roads crossing dambos, rivers and in some other places of ecological interest.

Vegetative materials were dug out and put in black polythene bags; water was poured in and then the bags were tied at the mouth. The most promising star and guinea grass materials based on one growing season single row nursery observation were put in two trials respectively as follows:

Trial 1: Star grass strains evaluation trial

Twenty-four entries from the southern African region and local collections were put in a split-plot design trial with two replicates. The plots which measured 9 square metres were split two-ways into three nitrogen fertilizer application rates of 20, 40 and 60 kg N/ha applied in the form of calcium ammonium nitrate (26% N) and three cutting regrowth intervals of 3, 6 and 9 weeks respectively.

Trial 2: Guinea grass (*Panicum maximum* Jacq.) strains evaluation trial

Fifteen collections, mostly indigenous to Malawi were planted in the same design as described in Trial 1. The only difference was that fertilizer rates of 0, 40 and 80 kg N/ha were applied. In both trials, the grasses were cut, weighed fresh and subsampled for the determination of dry matter after oven drying at 85°C for twenty-four hours.

RESULTS AND DISCUSSION

1. Star grass

Yield data for the star grass strains for the 1984/85 and 1985/86 growing seasons are presented in Tables 1, 2, 3 and 4. Two accessions, East Coast B and No.343 Star gave the highest forage dry-matter yields and these were in excess of 5000 kg/ha. These are the more robust growing star grasses, with larger stolon and leaf material than the small-slendered leaf and stolon materials. Second ranking were those strains of 4000 kg/ha yield levels. These were Chololo, Ichinga, Monzi, Misuku, Camper Down, Thunda and Chinunkha. These were of intermediate stolon material. The least amounts of forage were produced by the three Malawian collections, Nyungwe, Meru and S.E. Namwera all of which gave yields of less than 2500 kg/ha. These were materials least robust in growth and appearing less aggressive in that their stolon growth was rather restricted; hence they formed open turfs. The two commercially popular cultivars, Muguga and No.2 Star, that have since been grown at Chitedze Research Station, were intermediate, giving yields of about 3500 kg/ha.

The variability in forage productivity is explained by the fact that there were two different species in this collection. In the absence of critical taxonomic and botanical variety description, it was obvious that the material demonstrated a lot of physical differences. Plants that fitted the description with respect to *Cynodon dactylon* (Harlan and de Wet, 1969) were less robust in their growth habit. The more robust material probably belonged to *C. nlemfuensis* (Clayton and Harlan, 1970; Harlan, 1970).

Table 1. Forage DM yields (kg/ha) of *Cynodon* cultivars across two replicates in response to cutting regrowth intervals (1984/85 season).

Cultivars	3 weeks	6 weeks	9 weeks	Mean
1. Nyungwe	1840	2078	3303	2407
2. Chololo	2537	4088	5902	4142
3. East Court A+	2790	3153	4640	3528
4. Durban+	2053	2880	4828	3254
5. Thornville	2183	3070	4970	3408
6. Ichinga	2455	4450	5407	4104
7. Muguga	2393	3027	4690	3370
8. Monzi No.2+	2210	4860	6950	4680
9. Baka	2142	2618	4492	3083
10. Phoka Court	2150	3452	5375	3659
11. No.171 Star+	2810	3777	5538	4042
12. Coast Gross II+	2613	2658	4532	3268
13. No.2 Star	1657	4043	4702	3467
14. Misuku	3597	5007	5758	4787
15. No.161 Star+	2625	3043	5565	3744
16. Chilambula	2335	2858	6027	3740
17. Camper Down+	2832	5883	4893	4536
18. No.343 Star+	4570	4700	6107	5126
19. S.E. Namwera	3198	2889	2503	2863
20. Thunda	4175	3538	4677	4130
21. Monsi No.1+	2748	3418	4472	3546
22. Chinunkha	3865	4203	4820	4296
23. Meru	2308	2213	2845	2456
24. East Court B+	3105	4205	8105	5138
Means	2716	3589	5042	

S.E. of cultivar means ±640*
S.E. of cutting intervals means ±121**
S.E. of interaction ±209*
Overall C.V. 38%
\+ introduced entries
Where * is significance at P=0.05
** is significance at P+0.01

Increasing nitrogen levels generally resulted in significantly higher yields (P=0.05), but some strains were less responsive to nitrogen depending on the cutting regrowth intervals. Materials with a generally open turf responded poorly and lacked a response to increasing nitrogen fertilization. This was particularly true of the local Malawian ecotypes, Nyungwe, Phoka Court, Chololo, Thunda, Meru and a few imported strains, No.161 Star, No.2 and Thomville. There was also a significant increase in forage DM yields in response to increasing cutting regrowth intervals (P=0.01). This was no doubt a consequence of increased forage maturity.

During the 1985/86 growing season, all strains responded to increased cutting regrowth intervals from 3 to 9 weeks (P=0.001) as shown in Table 3. There was also a significant response to increasing levels of nitrogen fertilization, although the levels of 20 and 40 kg/ha were not statistically different. The strains

Thornville, Baka, Misuku and No.161 Star were not responsive to increasing nitrogen fertilization (Table 4). In the analysis, the differences between cultivars did not turn out significant, however, the largest amounts of forage, in excess of 8000 kg/ha, were given by the strains East Coast A, Coast Cross II, No.343 Star and Durban. The least amounts of forage, 6,500 kg/ha or less, was given by the strains, Meru, East Coast B, Chilambula and Phoka Court. The fact that in the second harvest year, No.2 Star fell in the top ranking group while Muguga maintained its position in the intermediate yielding category, shows that Star No.2, once it is fully established, has a high yielding potential.

Table 2. Forage DM yields (kg/ha) of *Cynodon* cultivars across two replicates in response to nitrogen fertilizer rates (1984/85 season).

Cultivars	N1=20	N2=40	N3=60	Mean
1. Nyungwe	2360	2512	2349	2407
2. Chololo	4130	4208	4088	4142
3. East Court A+	3075	3850	3658	3528
4. Durban+	2835	3520	3407	3254
5. Thornville	3483	3473	3267	3408
6. Ichinga	3725	4358	4228	4104
7. Muguga	2972	3465	3673	3370
8. Monzi No.2+	4760	4605	4675	4680
9. Baka	2917	2712	3623	3083
10. Phoka Court	3114	4052	3812	3659
11. No.171 Star+	3355	4228	4542	4042
12. Coast Gross II+	2470	3692	3642	3268
13. No.2 Star	3380	3625	3397	3467
14. Misuku	4087	5012	5263	4787
15. No.161 Star+	3978	3777	3478	3744
16. Chilambula	3198	3893	4128	3740
17. Camper Down+	3787	4883	4938	4536
18. No.343 Star+	4813	5053	5510	5126
19. S.E. Namwera	2695	2675	3220	2863
20. Thunda	3802	4627	3962	4130
21. Monsi No.1+	2822	4067	3750	3546
22. Chinunkha	4358	3978	4552	4296
23. Meru	2292	2483	2592	2456
24. East Court B+	4902	4660	5853	5138
Means	3471	3892	3984	

S.E. of cultivar means ±640*
S.E. of Nitrogen means ±137*
S.E. of Interaction ±671NS
Overall C.V. 38%
+ Introduced entries
Where * is significance at P=0.05
NS is not significant.

2. Guinea grass

Most of the locally collected strains have a higher yielding potential than the local standard cultivars, Ntchisi Panic and Hamil Panic. Notable in this case are selection H, selection O and Chololo Panic (Tables 5 and 6). These are generally leafier material which are generally of a very good regrowth potential, much better than either Ntchisi or Hamil Panic. The least producing were selections X and Makueni Panic, both of which are low growing and finer-leaved types. Both these strains were slow to establish a full canopy; as a result, they suffered considerably from weed competition during the establishment. The fact that they were smaller plant types could be explained by their belonging to a lower ploidy level than the majority of the more robust types.

Table 3. Forage DM yields (kg/ha) of Cynodon cultivars across two replicates in response to cutting regrowth intervals (1985/86 season).

Cultivars		3 weeks	6 weeks	9 weeks	Mean
1.	Nyungwe	4430	6022	11883	7445
2.	Chololo	4498	6354	12934	7929
3.	East Court A+	6081	9536	13545	9654
4.	Durban+	5022	7751	11335	8036
5.	Thornville	4068	7865	9606	7180
6.	Ichinga	4463	6614	11891	7656
7.	Muguga	4357	6376	10390	7041
8.	Monzi No.2+	3857	7644	8555	6685
9.	Baka	3817	7320	10510	7215
10.	Phoka Court	4202	6356	8962	6507
11.	No.171 Star+	3408	7797	10349	7184
12.	Coast Gross II+	6658	8345	11196	8733
13.	No.2 Star	5951	6969	11851	8257
14.	Misuku	5246	5538	9540	6774
15.	No.161 Star+	3634	6903	11189	7242
16.	Chilambula	5259	5756	8258	6424
17.	Camper Down+	5091	6775	12341	8369
18.	No.343 Star+	4397	9006	1 918	8440
19.	S.E. Namwera	4762	6826	9064	6864
20.	Thunda	5157	5620	10762	7186
21.	Monsi No.1+	3985	8073	9536	7198
22.	Chinunkha	5757	6393	11623	7924
23.	Meru	3610	6182	9279	6357
24.	East Court B+	4942	6053	11556	6357
	Means	4694	7003	10782	

S.E. Cultivar ±623NS
S.E. Cutting intervals
+ Introduced entries ±331
Where *** is significance at P=0.001
NS is not significant.

All strains significantly increased in their forage productivity in response to increasing cutting regrowth intervals. While the response to increasing nitrogen fertilization turned out significant, there was a tendency for same strains to respond less to increasing nitrogen fertilization beyond N_2 which is 40 kg N/ha. Notable in this regard are selections C, M, J, K, D, H, B, Ntchisi Panic and Hamil Panic.

Table 4. Forage DM yields (kg/ha) across of Cynodon cultivars two replicates in response to nitrogen fertilization (1985/86 season).

Cultivars		N1=20 kg/ha	N2=40 kg/ha	N3=60 kg/ha	Mean
1.	Nyungwe	7448	7256	7631	7445
2.	Chololo	7083	7894	8809	7929
3.	East Court A+	8822	9975	10164	9654
4.	Durban+	7396	7346	9364	8036
5.	Thornville	7283	7584	6673	7180
6.	Ichinga	7997	7162	7809	7656
7.	Muguga	6616	7386	7123	7041
8.	Monzi No.2+	5780	6865	7410	6685
9.	Baka	6774	8003	6869	7215
10.	Phoka Court	6230	6703	6588	6507
11.	No.171 Star+	6540	6729	8284	7184
12.	Coast Gross II+	8695	8413	9091	8733
13.	No.2 Star	6880	8656	9235	8257
14.	Misuku	7472	[illegible]453	6399	6774
15.	No.161 Star+	7436	7454	6836	7242
16.	Chilambula	6415	6058	6799	6424
17.	Camper Down+	7785	8578	8744	8369
18.	No.343 Star+	8961	8326	8033	8440
19.	S.E. Namwera	6593	6198	7863	6884
20.	Thunda	6569	7513	7476	7186
21.	Monsi No.1+	6414	6924	8256	7198
22.	Chinunkha	7216	8716	7840	7924
23.	Meru	6171	5840	7060	6357
24.	East Court B+	6698	7899	7954	7517
	Means	7136	7497	7846	

S.E. of Cultivars $\pm$623NS
S.E. of Nitrogen levels $\pm$141***
+ Introduced entries
Where *** is significance at P=0.001
NS is not significant.

Table 5. Forage DM yields (kg/ha) of *Panicum* strains across two replicates in response to cutting intervals.

Strains	3 weeks	6 weeks	9 weeks	Mean
1. Selection G	9939	9999	18211	12716
2. Ntchisi Panic+	9167	8848	13443	10486
3. Selection M	9022	7307	17133	11154
4. Selection J	7010	11033	22389	13477
5. Makueni Panic+	4852	6256	8485	6531
6. Selection X	4570	6607	6986	6054
7. Selection K	7948	9489	11671	9703
8. Selection D	7690	9287	16437	11138
9. Selection H	15723	16338	32473	21521
10. Selection O	10114	18105	22501	16907
11. Selection O	6696	10495	20981	12724
12. Selection I	7588	10924	16782	11764
13. Hamil Panic*	10592	14062	22776	15810
14. Chololo Panic	9329	17406	18039	14925
15. Selection B	8941	10076	15659	11559
Means	8614	11082	15597	

S.E. of strains ±1954**
S.E. of cutting intervals ±825***
+ Local checks
Where ** is significance at P=0.01
*** is significance at P=0.001.

Table 6. Forage DM yields (kg/ha) of Panicum strains across two replicates in response to nitrogen fertilization levels.

Strains	N1=0 kg/ha	N2=40 kg/ha	N3=80 kg/ha	Mean
1. Selection O	9160	14889	14101	12716
2. Ntchisi Panic+	8979	11297	11182	10486
3. Selection M	8769	12184	12509	11154
4. Selection J	9117	15575	15739	13477
5. Makueni Panic+	4589	5569	9435	6531
6. Selection X	6368	5485	9435	6054
7. Selection K	8128	10382	6309	9703
8. Selection D	8506	11645	10598	11128
9. Selection H	14584	26342	13264	21521
10. Selection D	14592	15531	23688	16907
11. Selection O	10713	12561	17564	12724
12. Selection I	9890	13085	14900	11764
13. Hamil Panic*	12801	17070	13318	15810
14. Chololo Panic	12887	13622	15266	14925
15. Selection B	10755	12645	11276	11559
Means	9923	13392	13979	

S.E. strains ±195NS
S.E. Nitrogen levels
+ Local checks ±825***
Where *** is significance at P=0.001
NS is not significant.

CONCLUSION

While the nitrogen fertilization regimes employed in this study were not aimed at coming up with a complete nitrogen response profile recommendation, it was important as a selection tool in demonstrating the necessity of considering low fertilizer input management. In the early evaluation stages it is important to appreciate materials that may not positively respond to high fertilization management as these have potential for eventual use in smallholder farming systems where inorganic nitrogen fertilizers may be lacking due to high cost.

The results show that the standard cultivars of star grass namely No.2 star and Muguga and the three standard guinea grass cultivars, Ntchisi Panic, Hamil Panic and Makueni could be replaced by some more superior locally selected strains.

Phoka Court and Misuku star grass strains which have not demonstrated a response to high fertilization management were collected from sites characterised by acid infertile soils. The lack of positive response in these two and other similar strains could be an adaptation to these poor growing conditions. This potential ought to be exploited in greater detail.

This argument holds true also for the guinea grass strains that showed this potential.

Panicum maximum strains have shown variability that warrants selection to replace Ntchisi, Hamil and Makueni Panics by the more robust, leafier ecotypes.

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EVALUATION OF *DESMODIUM ADSCENDENS* THROUGH VEGETATIVE PROPAGATION IN NATURAL AND PLANTED PASTURES

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Abstract

The natural grasslands of Uganda comprise about 80% of the total land area and are regarded as a national asset because they support nearly 99% of Uganda's livestock and game animals. They contain numerous indigenous forage species which have not been developed to increase the productivity of these grasslands which is below their potential.

The objective of the study was to evaluate a local forage legume (Desmodium adscendens *[Sw.] DC) when planted vegetatively in ley and natural pastures.*

The results indicated that D. adscendens *established well when vegetatively planted in ley and natural pastures. However, it was more successful in ley than in natural pastures. The legume has a high potential for dry-matter yield, % crude protein and N_2 fixation.* D. adscendens *exhibited remarkable persistence.*

It is, thus, suggested that more detailed studies using an interdisciplinary approach be conducted to determine the contribution of the legume to pasture productivity, animal production, soil fertility and subsequent crop yield.

INTRODUCTION

The natural grasslands of Uganda comprise about 80% of the total land area (Horrell and Tiley, 1970) and are regarded as a national asset because they support nearly 99% of Uganda's livestock and game animals. Unfortunately, the productivity of these grasslands in terms of herbage quality and quantity and animal production is extremely below their potential. For example, estimated milk production per cow ranges from 400-600 litres in a six- to seven-month lactation period, and this is considerably below that of cows grazing improved grass/legume pastures. Even the ley pastures which constitute a small proportion of the natural pastures are below their potential.

Their potential could be increased by incorporating forage legumes such as *Stylosanthes gracilis, Desmodium intortum, D.*

uncinatum, *Centrosema pubescens*, *Macroptilium atropurpureum*, *Medicago sativa* and *Indigofera hirsuta* (Stobbs, 1969a,b; Otim, 1973; Horrell and Court, 1965; Mugerwa, unpublished; Sabiiti, 1979; UNDP/FAO, 1973).

However, one of the major constraints in the improvement of pastures has long been the consistent lack of pasture seeds (both legumes and grasses). Nearly all the pasture seeds are imported and are very expensive (about 5,000/= per kg of legume seed) and are still scarce in the country. The situation was further aggravated by political instability in the last 15 years or so and nearly all the pasture germplasm is confined to research stations or has disintegrated as at Kabanyolo Makerere University Farm. Furthermore, there is evidence to show that most of the recommended forage legumes fail to combine both productivity and persistence for a long time under various pasture management practices and ecological zones (Sabiiti, 1979).

To overcome some of the above constraints, it is important to evaluate local pasture species, especially legumes before they are extinct under the current rapid environmental degradation in the country. The need to develop local pasture species has long been emphasised by Henderlong (1973) and others.

One of the forage legumes which we have identified is *Desmodium adscendens* (Sw.) DC. It has been observed to grow well in the Lake Victoria crescent region of high rainfall (1000-1500 mm/annum). The crescent region is important for dairy farming but there is scarcity of legumes on these farms. The legume appears to be grazed by livestock and game animals, especially during the dry season when the grasses are very dry. It roots at the nodes, and it could be established vegetatively to reduce the dependence on importation of expensive seeds. This method has been used successfully in Kenya to establish *D. intortum and D. uncinatum* (exotic species) by Keya *et al.* (1971). However, there is no data on this aspect. The legume makes excellent fodder and could be used as a soil cover and green manure. In Indo-China, Malaysia, East and South Africa, it is planted in tea and coffee plantations as a cover and for green manure.

However, no work has been done on this legume here to determine its contribution to pasture productivity. The objectives of the study were to determine a method of establishment, assess dry-matter yield, feeding value (CP) and persistence of *D. adscendens* under various management practices.

MATERIALS AND METHODS

Study Area Description

The first study (under planted pastures) was conducted at Kabanyolo Makerere University Farm. Kabanyolo is in the fertile lake crescent area, 19 km north of Kampala ($0^{o}28'$N, $32^{o}37'$E, 1,200 m.a.s.l.). The upland soils of Kabanyolo are classified as Latosols, or ferrallitic soils. They are deep, highly drained red soils. The pH varies from 5.0-5.8 (Mohiddin and Mukiibi, unpublished; Reid *et al.*, 1973) with a very low level of phosphorus (4 ppm P Truog), medium potassium (18 mg/100 g) and ample organic matter (3.1%) (Olsen and Moe, 1971).

The area has a moist tropical climate with mean maximum temperatures varying from 28.5°C in January to 26.0°C in July and minimum temperatures from 17.4°C in April to 15.9°C in July and August. Mean annual rainfall is about 1,300 mm, with two peaks in April and November and two periods of low rainfall in January and July when the monthly mean drops to 60 mm.

The second study (under natural pasture conditions) was conducted at Buwambo, 24 km north of Kampala (0°35'N, 32°34'E, 1300 m.a.s.l.). The soils and climate of the area are similar to those of Kabanyolo. The vegetation is dominated by a natural low medium tropical deciduous forest and abundant elephant grass (*P. purpureum*) in areas that have been cleared. Other important vegetation include perennial shrubs, native pasture legumes; *D. adscendens* being the dominant one followed by *Neonotonia wightii* and grass species *Cymbopogon, Imperata, Digitaria, Panicum* and *Brachiaria*. The area is commonly grazed by cows, goats and sheep.

METHODOLOGY

Study I: Evaluation of *D. adscendens* under planted pastures

Mature stem cuttings (15 cm long) were planted at a spacing of 0.5 x 0.5 m into an established pasture of *Chloris gayana* Kunth., *Cynodon dactylon* Linn., and *Brachiaria brizantha* at Kabanyolo University Farm. The stem cuttings were collected from Buwambo, 24 km north of Kampala where the legume grows naturally in a mixture of *P. purpureum, Brachiaria* spp., *Hyparrhenia* spp., *Imperata cylindrica* and *Panicum* spp. They were planted into holes of about 7 cm deep and firmed with the soil. The pasture paddock was divided into four plots (10 x 10 m) each and were excluded from grazing for ten months. Planting was done during the long rainy season in March in 1979 to ensure maximum establishment. Before planting, single superphosphate at the rate of 250 kg/ha was broadcast onto the plots to promote legume root growth (Olsen and Moe, 1971).

Establishment

Observations on the establishment of the legume were made after three and six months from planting because after that the senior author left the University. The total number of cuttings which had sprouted were determined.

Dry-Matter Yield, Crude Protein and Persistence

These parameters were determined in 1986 following the senior author's appointment at the University. However, the paddock had been grazed several times in the past but no observations were made. Conventional methods for herbage sampling of the old plots and dry-matter estimation were used. Crude protein content was determined by the Marcro-Kjeldhal method (AOAC, 1965).

Study II: Evaluation of *D. adscendens* under natural pastures

Four plots (10 x 10 m) were randomly located at Buwambo, where the legume grows naturally. Mature stem cuttings of 15 cm long were planted onto a natural pasture dominated by *B. brizantha*, *I. cylindrica*, *H. rufa* and *P. maximum*. Any existing legume was removed before planting. The cuttings (one cutting/hole) at a spacing of 0.5 x 0.5 m were planted in March 1979 during the rainy season to ensure maximum growth. There was no application of single superphosphate fertilizers.

Establishment

Observations on establishment of the legume were made after three and six months from planting because of similar reasons as in the above.

Dry-Matter Yield, % CP and Persistence

These were determined in 1986 from the old plots. Similar sampling methods and dry-matter estimation and crude protein content analysis were used as above. A 't' test was used to compare the treatment means of the two types of pastures as outlined by Zar (1984).

RESULTS

Establishment of *D. adscendens* in Ley and Natural Pastures

The results in Table 1 show that *D. adscendens* was successfully established through vegetative propagation under both pastures (ley and natural); however, a significantly ($P<0.05$) higher percentage of establishment was obtained under ley pastures. This is expected because of the excellent seedbed conditions obtained in this method.

The cuttings started producing shoots after three weeks from planting and by the fourth month most of the plants were fully established with many leafy shoots (5-10 shoots/plant). Growth was vigorous but especially under ley pastures. Unfortunately, there were no further observations on the performance of these plants after 1979 because the senior author left Makerere University after completing his M.Sc. research programme.

Persistence

The legume has persisted very well both at Kabanyolo and in Buwambo under grazing, nearly eight years from planting. *D. adscendens* is more abundant in nearly all the paddocks at Kabanyolo than the introduced forage legumes mentioned in the introduction. The same observation is true under natural pastures. The legume has spread over large areas where it was not abundant before. Also the legume nodulates profusely without inoculation, especially under ley pastures, so it could be fixing N_2 as most of the nodules exhibited red pigment when cut open. The legume is prostrate and this makes it better adapted to grazing conditions.

Table 1. Total number and percentage of vegetatively established plants of *D. adscendens* in ley pastures at Kabanyolo Makerere University Farm (A) and at Buwambo (B) in 1979.

Site	Plot	Number of established plants	% Establishment
A	C	360	90.0
	D	360	90.0
	E	350	87.5
	F	370	92.5
Mean		360$\pm$8	90.0$\pm$2
B	G	265	66.3
	H	258	64.5
	I	300	75.0
	J	290	72.5
Mean		278.3$\pm$20	69.6$\pm$5

't' - test $P<0.05$, $\pm$SD, n=4.

Dry-Matter Yield and % Crude Protein

It is clear from Table 2 that *D. adscendens* has a high potential of productivity in terms of DM yield (2830 and 1620 kg/ha) and % CP (22.5 and 17.8) in ley and natural pastures, respectively.

Table 2. Total DM yield (kg/m^2) and % crude protein of *D. adscendens* collected from ley pastures at Kabanyolo Makerere University Farm (A) and from natural pastures at Buwambo (B) in 1986.

Site	Plot	DM yield kg/m^2	% CP
A	1	.218	21.5
	2	.258	21.8
	3	.357	24.3
	4	.300	22.4
Mean		.283$\pm$0.06	22.5$\pm$1.3
B	1	.146	15.8
	2	.178	18.5
	3	.190	19.4
	4	.135	17.6
Mean		.162$\pm$0.03	17.8$\pm$1.5

't' - test $P<0.05$; $\pm$SD, n=4.

The plants under ley pastures produced significantly ($P<0.05$) higher DM yield and % CP. These are two of the major indices for evaluating a new cultivar.

The plants under natural conditions mainly suffered from severe competition from shrubs, trees and tall grasses of *Hyparrhenia* spp., *P. purpureum* and *I. cylindrica*. Management under natural pastures would require removal of tall species and topping of the existing vegetation to reduce shading and competition.

DISCUSSION

The genus *Desmodium* has about 200 species (perennial or annual) which occur in temperate and tropical regions where they are used for grazing (Whyte *et al*., 1953). Unfortunately, only two species (*D. intortum* and *D. uncinatum*) have been studied in detail in Uganda (Mugerwa, unpublished; Otim, 1973; Olsen, 1973; Reid *et al*., 1973; Olsen and Moe, 1971; Ochodomuge, 1978). This is also true for other countries (see Kategile, 1984; Anon, 1985). Even then the success of these two legumes in pastures in Uganda has been limited by lack of sufficient pasture seed and other limitations which have been reviewed by Sabiiti (1979).

Therefore, the results we have reported on *D. adscendens* are promising in that we can reduce dependence on imported seeds of exotic species and rely on a local legume species that establishes well by vegetative propagation and has a high potential for DM yield and % CP. It has shown admirable persistence in both ley and natural pastures under grazing conditions. However, we do not know the stocking rate and frequency of grazing that were used because no records were made. The legume appears to be dispersed by animals through either the seeds which stick on their skins and are dropped or by the broken stems which get trapped between the hoof and are later dropped in other paddocks. Also humans could have assisted in the spread of the legume on the farm.

The profuse natural nodulation of the legume might be important in increasing pasture productivity, soil fertility and subsequent crop yields. Currently, we have no published data on *D. adscendens* in East Africa to compare with although Keya *et al*. (1971) have shown that other *Desmodium* species were easily established from root splits (40-80%). In South America, Lazier unpublished did not clearly indicate how the legume was established. In Taiwan, Byran (1969) successfully established *D. intortum* and *D. uncinatum* by planting individual splits.

Since *D. adscendens* occurs abundantly in the regions that are important for dairy industry in Uganda, farmers should be encouraged to collect and plant the legume in their paddocks and then apply single superphosphate to encourage root formation and growth. The early establishment and higher survival rate in ley pastures were partly attributed to single superphosphate. Once the plants have established, they form several prostrate shoots which grow rapidly, and these can again be used to plant in other paddocks.

Future Research

Our present data are not yet conclusive and since there is little information on this important legume, there is a need to investigate further other indices of evaluation, namely, response to defoliation (mechanical or biological), regrowth physiology to understand mechanisms of persistence, nutrient analyses, digestibility studies, grazing trials, (voluntary intake) and animal production (live weight gain or milk production), N_2 fixation and soil fertility and crop production from pastures previously planted to *D. adscendens*.

Our current evaluation programme of *D. adscendens* at the University Farm is geared towards the above studies using an interdisciplinary approach. We have got soil scientists, microbiologists, animal nutritionists, agronomists and physiologists because we believe we can achieve great success in a short time.

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THE SCREENING OF PERENNIAL *TRIFOLIUM* SPECIES MAINLY FROM THE ETHIOPIAN HIGHLANDS AND THEIR POTENTIAL FOR USE IN PASTURE

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Abstract

Spaced plants of 98 accessions of perennial Trifolium *spp. mainly from the Ethiopian highlands were planted at Shola, Addis Ababa, Ethiopia in June 1985 for initial screening. The objective was to select those suitable for use on Vertisols which are subject to waterlogging in highland pastures with an extended dry season and periodic frosts. Total annual rainfall for 1985 and 1986 was 1050 mm and 1198 mm respectively. There were more frosts in 1985.* T. cryptopodium *followed by* T. burchellianum *had the highest DM production and persistence during the dry season, but the latter had poor flowering.* T. semipilosum *including cv Safari had lower production but very good flowering.* T. repens *included as a control had fair performance. None of the accessions were affected by frost. Results indicate that these clovers have potential for use in pastures particularly on fallow areas and for soil conservation. Nine accessions were selected for further evaluation in mixture with grass under cutting or grazing.*

INTRODUCTION

The highlands of Eastern Africa, in this context land above 1800 m, cover 70,000 km^2 of which 60% is in Ethiopia. They contain the highest human and livestock densities and are the most intensively cultivated (Getahun, 1978; Morgan, 1982; Jahnke and Asemenew, 1983). The major function of cattle in the Ethiopian highlands is traction. In the highlands of East Africa, cattle are primarily kept for milk. In fact the largest proportion of dairy production in Africa is in these highlands with Kenya leading (Mukasa-Mugerwa, 1980). The highlands therefore represent ideal smallholder mixed farming systems and have great potential for livestock production.

Unfortunately, the highlands are plagued by the same constraints as elsewhere in Africa of inadequate livestock feed particularly during the dry season. Natural pastures provide about 65% of the feed resources, and the rest are provided by crop residues (Jahnke and Asemenew, 1983). So one way of increasing livestock feed would be through pasture improvement. However, periodic frosts, extended dry periods, high acidity, extensive areas of Vertisols and Nitosols, each with its own peculiarities present special problems to legume introduction. On the other hand, highland pastures are rich in legume composition particularly the *Trifolium* spp. (Gillett, 1952; Gillett *et al.*, 1971; Mengistu, 1975; Thulin, 1983). Evaluation of annual Ethiopian clovers has shown that they have good potential for hay production (Kahurananga and Tsehay, 1984). In 1985 work was started in screening perennial clovers as research in Australia has shown that some of them have high potential for improving pasture production (Mannetje, 1964; Jones and Cook, 1981).

METHODS

The screening was conducted at ILCA Headquarters, Shola, Addis Ababa, Ethiopia (9° 2'N, 38° 42'E) at an altitude of 2380 m on a gently sloping site with seasonally waterlogged black clay soil typical of the bottomlands of the Ethiopian highlands traditionally used for hay production and grazing. The soil is slightly acidic (pH 5.8) and very deficient in P(8.68 ppm).

Ten seedlings, each seven to nine weeks old of 98 accessions of *Trifolium africanum* (2), *T. burchellianum* (23), *T. cryptopodium* (13), *T. semipilosum* (57), including cv Safari for comparison together with *T. repens* (1) (control) originally from Ethiopia (83), Kenya (11), Tanzania (1) and southern Africa (3) were transplanted into a well cultivated field at 1 m intervals on 24 and 25 June, 1985. TSP was applied at a rate of 40 kg P ha^{-1}. Two handfuls each of sheep manure were put in the holes and mixed with soil into which seedlings were transplanted. Observations were taken once every three weeks and included vigour, cover, stolon thickness, internode length, petiole length, middle leaflet surface area, inflorescences per plant, flowers per inflorescence and peduncle length. The plants were harvested in May 1986 and again in September 1986 and the material dried in an oven at 65°C for 24 hours for estimation of dry matter.

Daily weather records were available at the ILCA Shola weather station nearby.

RESULTS

The climatic data is presented in Table 1. The total annual rainfall for 1985 and 1986 was 1058 mm and 1198 mm respectively with a better spread in the later part of year (Showamare, 1986). Average maximum and minimum temperatures for both years were similar but there were more frost nights in 1985 even during the rainy season which stunted annual clovers in nearby plots.

The observations from the 980 plants are still being entered into the computer for cluster analysis in order to group plants according to their growth characteristics. Data so far recorded for the most important observations for each species are summarised in Table 2. The results show that *T. cryptopodium* had the highest DM production followed by *T. burchellianum* var. *johnstonii*. All varieties of *T. semipilosum* had lower DM with var. *semipilosum*, *glabrescens*, including cv Safari, *intermedium* and *brunellii* in that order. *T. repens*, *T. africanum* and *T. burchellianum* var. *oblongum* had the lowest DM production. Again *T. cryptopodium* and *T. burchellianum* had the best vigour or green leaf retention during the dry season. *T. semipilosum* varieties shed most of their leaves during the dry season and those which remained turned copper red.

Table 1. Climatic records at Shola for 1985 and 1986.

	Rainfall (mm)		Evapotr. (mm)		Air temperature °C Av. Max.		Av. Min grass lev.				No. of Frost night		Sunshine Duration	
	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986
Jan.	29	0	198	176	23.0	23.0	8.4	6.5	-5.5	-3.0	16	21	9.7	10.4
Feb.	0	44	185	139	23.6	23.3	8.3	10.6	-2.5	1.0	5	0	9.5	6.4
Mar.	24	71	187	188	24.6	23.5	10.0	10.6	-4.0	1.5	5	0	8.0	7.8
Apr.	110	217	160	129	22.7	22.3	11.0	11.8	-2.0	5.5	1	0	4.9	5.9
May	119	51	170	154	23.0	23.7	11.2	11.6	-0.5	1.5	2	0	7.3	8.2
June	94	226	149	100	22.6	20.9	10.5	10.8	-0.5	1.0	2	0	8.9	4.5
July	228	168	89	99	19.3	20.4	10.4	10.9	0.5	6.5	0	0	3.7	4.4
Aug.	280	260	82	111	19.7	20.7	10.7	10.4	0.5	2.5	0	0	4.1	4.5
Sept	138	124	133	127	20.6	21.1	10.5	9.9	3.5	-2.5	0	1	6.5	6.5
Oct.	37	37	175	177	21.4	22.0	9.4	8.1	-0.5	-2.0	1	5	8.9	8.9
Nov.	0	0	176	185	22.1	22.8	6.9	7.4	-3.5	-3.5	15	10	10.7	10.6
Dec.	0	0	175	1.7	22.0	22.9	7.1	6.5	-3.5	-4.0	10	10	9.8	9.7
Total	1059	1198									57	47		

Source: Showamare (1986).

Table 2. Average and range of the important observations of perennial Trifolium at Shola in 1985 and 1986.

Species and variety	Number of accessions	Dry season vigour (1-10)	DM weight per plant (gm)	Days to first flowering	% plants in flower
T. africanum	3	4(3-4)	69(20-176)	192(176-207)	60(50-70)
T. burchellianum var. johnstonii	23	6(4-9)	192(11-342)	185(182-252)	23(0-50)
T. burchellianum var. oblongum	1	5(5)	49(31-71)	139(139)	10(10)
T. cryptoodium	13	6(3-8)	224(42-569)	212(181-233)	49(30-80)
T. repens	1	5(5)	61(21-160)	183(183)	30(30)
T. semipilosum var. brunelli	1	1(1)	68(4-14)	221(221)	50(50)
T. semipilosum var. glabrescens	12	3(1-7)	111(11-240)	156(119-184)	98(90-100)
T. semipilosum var. intermedium	2	3(2-3)	87(55-120)	223(217-228)	50(50)
T. semipilosum var. semipilosum	42	4(1-7)	147(41-222)	205(166-231)	88(40-100)
Total	98				

The positions were reversed regarding flowering. *T. semipilosum* had profuse flowering with varieties *semipilosum* and *glabrescens* excelling. *T. africanum* had good flowering and *T. cryptopodium* was average. The one accession of *T. repens* had rather fair flowering. Both varieties of *T. burchellianum* had the worst flowering with some accessions not flowering at all. None of the accessions were affected by frost.

Besides the above characteristics, all the clovers showed good soil binding characteristics, demonstrated by the fact that most of the soil cracking during the dry season occurred mostly on spots where there was no clover growth. *T. cryptopodium* with its numerous matt-forming rhizomatous stems was most outstanding in this respect.

DISCUSSION

This is the first time that such a large collection of perennial *Trifolium* species from Ethiopia have been screened. It was rather surprising that the smallish often overlooked *T. cryptopodium* being evaluated for the first time surpassed the others in DM. This is partly due to its dense matt of stems with short internodes. It grows well in natural pastures with grasses such as *Andropogon abyssinica, A. amethystinus, A. distachyos, Pennisetum thunbergii* and *P. clandestinum* or Kikuyu grass. At one time it was briefly referred to as forming a valuable close sward under heavy grazing in association with *Digitaria scalarum* on Mt. Elgon (Gillett, 1952). The prostrate growth habit and its small leaves and short internodes makes it ideal for sheep grazing at high altitudes from about 2600 m - 3000 m. The matt-forming growth habit which binds soil together also makes it ideal for soil conservation. Its only problem is that its pods shatter easily after ripening. There is therefore need to study the seed ripening characteristics in order to devise efficient means of harvesting.

The other species which showed good productivity and which persisted well during the dry season was *T. burchellianum* var. *johnstonii*. Its ability during the dry season was also noted in early observations in Kenya and Australia (Bogdan, 1956; Britten, 1962; Mannetje, 1964). This characteristic is rather surprising as this species is normally distributed in moist grasslands and open glades in forests where rainfall is above 1000 mm (Gillett *et al.*, 1971; Thulin, 1983). This species is found growing with *T. cryptopodium*. Its major limitation is the poor flowering and hence seed production. This was also observed in one of the early glasshouse experiments where it failed to flower altogether (Mannetje and Pritchard, 1968). However, in this trial there were two accessions, one from Ethiopia and the other from Tanzania which had good flowering. There are therefore possibilities for selection. This species has good potential for use in pasture for both cattle and sheep. It is also suitable for soil conservation.

Although the average productivity of *T. semipilosum* was lower than the two preceeding species, there were some accessions which did well. It is rather surprising that var. *glabrescens* including cv Safari faired poorly. The latter is doing well in subtropical areas of Australia (Jones and Cook, 1981). Although most of the accessions lost their leaves and those leaves which remained turned copper red during the dry season, they responded very fast to the onset of rain. This species had excellent flowering, and the pods do not shatter so easily, making it more suitable for seed production. It also grows well naturally with grasses in pasture, and it is found in a very wide range of altitudes, edaphic conditions for both cattle and sheep and for soil conservation. It seems to withstand very heavy grazing in communal natural pasture. The ability to persist under grazing has also been noted under Australian conditions (Sproule *et al.*, 1983).

This screening trial has shown that the perennial *Trifolium* species have good potential for use in pasture. They could be used in establishing new pastures or on fallow areas including marginal areas. They could also be useful in reseeding degraded areas. It is important to continue making selections as evaluations continue. In this screening, four accessions of *T. cryptopodium* (ILCA Nos.7621, 9391, 9398, 9461), three of *T. burchellianum* var. *johnstonii* (ILCA Nos. 10179, 10207, 12481) and of *T. semipilosum* var. *semipilosum* (ILCA No.7642,8025) were selected for the next stage of evaluation in mixture with grasses under cutting management and grazing.

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YIELD AND QUALITY OF *LABLAB PURPUREUS* ECOTYPES IN HIGH ALTITUDE SEMI-ARID LANDS IN KENYA

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Abstract

Dry-matter production, forage nutritive value and seed yield of Lablab purpureus *ecotypes were studied over a two year period. Total and green leaf DM production ranged from 2000 kg to 12000 kg ha^{-1} and 400 kg to 3300 ha^{-1} respectively. The leaf/stem ratio declined by 3.7 to 4.5 times with maturity.* In vitro *dry-matter digestibility and protein content of green leaf and stem declined by 10% to 15% units and 3% to 5% units respectively. Phosphorus content was not affected by forage maturity. Seed yields of 400 to 1800 kg ha^{-1} with crude protein content of 24% to 29% (DM basis) was recorded. It was concluded that the DM yield, forage nutritive value and seed yield make* Lablab *an attractive proposition in livestock/crop farming systems.*

INTRODUCTION

Over 200 genotypes of *Lablab purpureus* are recognised (Pulseglove, 1968). This germplasm has been exploited as a source of human food (Skerman, 1977), forage for livestock (Hamilton *et al.*, 1970; Hendricksen and Myles, 1980) and as green manure or cover crop (Pulseglove, 1968).

In Kenya, *Lablab* finds its greatest use in the small-scale sector mainly as a source of grain for human consumption. However, the current trends in farming emphasise the use of multipurpose crops that fit into integrated livestock/crop farming patterns. The investigations reported examined the potential contribution by *Lablab* in livestock/crop farming systems.

MATERIALS AND METHODS

The experiments were conducted at the Lanet Beef Research Station, Nakuru, altitude 1860 m. Precipitation, mean maximum and minimum temperatures during the trials periods were: 611 mm and 623 mm; 24.5^{o}C and 24.8^{o}C; 9.5^{o}C and 9.2^{o}C in 1982 and 1983 respectively. The soil is a deep sandy loam with good water holding capacity. The major nutrient status was: K(me) 1.0, P(ppm) 1.9 and N(%) 0.10 with a pH(H_2O) of 5.5.

The cultivar Valo (black seeded) was introduced from India. Nakuru (black and brown seeded) and Kakamega (black seeded) on the other hand, are local ecotypes grown in the Rift Valley and western Kenya respectively. Seeds were sown after 25 mm of germination rain was received each year at a rate of 7 kg ha^{-1}. Plots (5 m^2) were arranged in randomised complete blocks with four replications. At sowing, fertilizers were applied at the rates of 10 kg P ha^{-1}, 4 kg K ha^{-1} and 0.40 kg Cu ha^{-1} as single superphosphate, muriate of potash and copper sulphate respectively.

Plots were harvested at monthly intervals after three-months' growth from germination. Harvests were taken from 1 m^2 quadrats excluding the guard row. Harvest four did not include the seed yield components. Material was cut approximately 5 cm above the ground and the bulk weight taken. Any shed leaves were separately collected and weighed. A subsample from each replicate was separated into leaf and stem fractions. The separated fractions and a subsample from the abscissed leaves were weighed and subsequently dried at 75°C for 24 hours for dry-matter (DM) determination. Seed pods were included in the stem DM yield in harvests one to three. The dried green leaf and stem fractions were ground (2 mm) and used for determination of dry-matter digestibility, crude protein (%N x 6.25) and phosphorus contents. Nitrogen was estimated using the micro-Kjeldahl method (Havilah *et al.*, 1977) and phosphorus by X-ray fluorescence spectroscopy. Dry-matter digestibility was estimated by *in vitro* digestibility method calibrated with lucerne of known *in vivo* digestibility. The data were subjected to analysis of variance.

RESULTS

All ecotypes nodulated effectively with cowpea rhizobia in the soil; 23, 27, 22 and 19 effective nodules were recorded in Valo, Kakamega, Nakuru (black seeded) and Nakuru (brown seeded) respectively. Time to flowering differed by 20 to 30 days (Figure 1).

Total green DM yields ranged from 2000 to 12000 kg ha^{-1}, and most of the yield was stem (Figure 1). Green leaf DM yields ranged from 400 to 3300 kg ha^{-1}. However, all ecotypes maintained green leaf DM yields above 2000 kg ha^{-1} between three and five months of growth. Leaf shedding increased with maturity. This was associated with a progressive decline, 3.7 to 4.5 times with time, in leaf/stem ratio according to the following models:

1. $Y = 1.51 - .33\,X \quad R^2 = .80$ (Valo)
2. $Y = 1.17 - .25\,X \quad R^2 = .76$ (Kakamega)
3. $Y = 1.25 - .28\,X \quad R^2 = .74$ (Nakuru, black seeded)
4. $Y = 1.41 - .31\,X \quad R^2 = .90$ (Nakuru, brown seeded)

Where Y is leaf/stem ratio and X is sampling time in months after sowing.

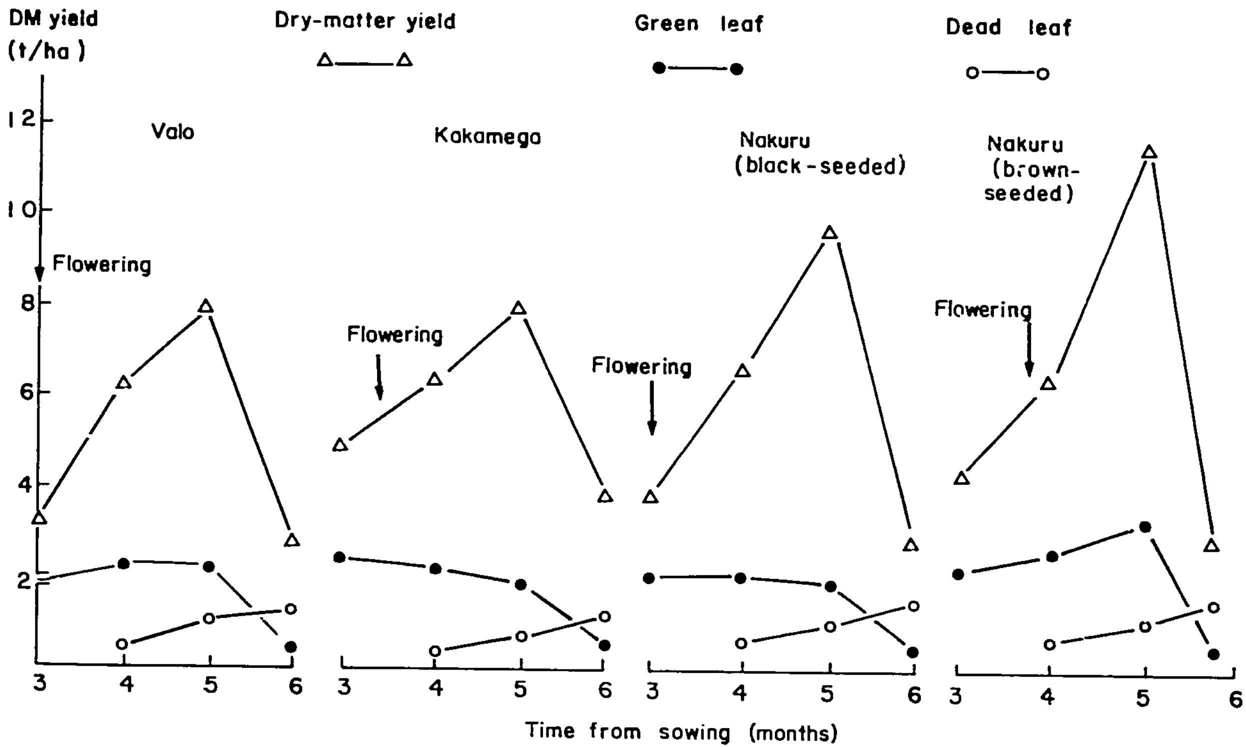
Trends of dry-matter digestibility, protein and phosphorus contents in green leaf and stem with time are shown in Table 1. Digestibility was higher ($P<0.01$) in leaf than stem but declined by 10% to 15% units over time in both fractions. The decline in leaf digestibility was slightly higher than in the stem fraction: 0.17, 0.17, 0.10 vs 0.14, 0.09, 0.12 and 0.08% units day^{-1} in Valo, Kakamega, Nakuru (black seeded) and Nakuru (brown seeded) for leaf and stem components respectively between three and six months of growth. Protein content was higher ($P<0.01$) in leaf than stem, and declined by 3% to 5% units in both fraction over

Table 1. Leaf/stem ratio, dry-matter digestibility, crude protein and phosphorus contents in green forage fractions.

Ecotype	Time(1)	Leaf/Stem ratio	Digestibility (%)		Crude protein (%)		Phosphorus (%)	
			Leaf	Stem	Leaf	Stem	Leaf	Stem
Valo	3	1.26d*	74.3b	56.8b	21.4	14.5b	0.38	0.41
	4	0.72c	66.5b	53.4b	19.5	14.0ab	0.36	0.40
	5	0.41b	61.3ab	49.6ab	18.4	13.7ab	0.35	0.44
	6	0.28a	58.4a	44.2a	17.6	9.1a	0.37	0.44
Kakamega	3	1.03c	75.8b	52.3b	20.3	13.1b	0.33	0.42
	4	0.47b	70.3b	50.9b	19.1	12.7ab	0.32	0.41
	5	0.41b	66.4ab	47.3ab	17.8	11.2ab	0.29	0.43
	6	0.28a	60.3a	44.1a	17.4	8.1a	0.3	0.46
Nakuru (black-seeded)	3	1.16c	72.9b	58.2b	20.5	13.4b	0.36	0.42
	4	0.43b	70.3ab	55.6ab	18.6	12.6ab	0.31	0.40
	5	0.29a	68.4ab	50.9ab	17.7	11.4ab	0.32	0.45
	6	0.31a	64.3a	47.4a	17.1	7.6a	0.38	0.44
Nakuru (brown-seeded)	3	1.17c	74.9b	56.3b	22.0	14.4b	0.36	0.43
	4	0.71b	72.3ab	53.4ab	19.8	13.5b	0.35	0.47
	5	0.60b	69.8ab	52.6ab	18.1	10.1ab	0.35	0.42
	6	0.31a	65.7a	49.3a	17.3	6.2a	0.33	0.45

(1) Time was in months from sowing.
* Means per attribute within an ecotype not followed by a common letter differ (P<.05) according to Duncan's multiple range test.

Figure 1. Total dry-matter yield, green leaf and dead leaf of Lablab purpureus ecotypes Valo, Kakamega, Nakuru (brown-seeded).



time. Phosphorus content showed no significant changes with time.

Seed yield was a function of seed pods m^{-2}. All ecotypes had an average of 2 seeds pod^{-1}. Nakuru (brown-seeded) out-yielded (P<0.5) the other ecotypes (Table 2). Seed protein content was similar (P>0.05).

Table 2. Component of seed yield: Seed yield and crude protein content in seed.

Ecotype	Components of seed yield Pods m^{-2}	Seed m^{-2}	Seed yield (kg/ha^{-1})	Crude protein (%)
Valo	190a*	232a	733.7a	28.5
Kakamega	172a	292a	655.9a	27.3
Nakuru (black-seeded)	166a	246a	409.4a	24.1
Nakuru (brown-seeded)	325b	860b	1812.1b	28.2

*Means within each column not followed by a common letter differ (P<0.05) according to Duncan's multiple range test.

DISCUSSION

The variation in time to flowering confirms the existence of physiological differences with *Lablab purpureus* ecotypes (Pulseglove, 1968). This variation could be exploited in selecting germplasm suitable to a particular area.

Green total and leaf DM yields were higher than those recorded for *Lablab purpureus* cv. Rongai (Murtagh and Dougherty, 1968; Hendricksen and Minson, 1986). The ceiling leaf DM yields suggested by Murtagh and Dougherty (1968) are lower than that contained in this study. Leaf retention characteristic exhibited by the Nakuru (brown seeded) ecotype indicated a useful attribute under grazing, and generally all ecotypes maintained more than 2000 kg ha^{-1} green leaf content longer in the growing season than cv. Rongai (Hendricksen and Minson, 1986).

The decline in DM digestibility and crude protein content in the foliage with maturity is consistent with reports on other tropical pasture legumes (Jones, 1969; Norton, 1982). This decline was also associated with increased rates of leaf fall. However, the green leaf fraction maintained favourable levels of protein and digestible fractions. This was probably due to retranslocation of nutrients from the senescing leaves. Phosphorus content varied least with maturity. Partly, this is because phosphorus is not subjected to extensive retranslocation between plant organs.

All ecotypes yielded more seed than was recorded by Davies and Hutton (1970) but lower, except Nakuru (brown-seeded), than was reported by Pulseglove (1968). The data on pods m^{-2} and seeds m^{-2} and their effects on final seed yield appear to suggest there were differences in seed size, hence a potential to select for high seed yield among the existing materials. The protein content in the seed further shows a legume with potential use as human food.

A substantial amount of leaf abscission occurred late in the season. This was the period (5 to 6 months of growth) when seeds were approaching maturity. As the shed leaves would not be available for grazing, studies are needed to investigate the time to optimise both the DM and seed yields. Overall, the DM yields, forage nutritive value, seed yield and its crude protein content show that *Lablab purpureus* would contribute considerably in livestock/crop farming systems.

ACKNOWLEDGEMENTS

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ADAPTATION OF FORAGE AND BROWSE LEGUMES TO THE SEMI-ARID MID-ALTITUDE REGIONS OF KENYA - AN INTERIM REPORT

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Abstract

The adaptation of 160 legumes of various growth forms is being studied at four sites in the semi-arid, mid-altitude districts of Machakos and Kitui in Kenya. The sites cover an altitude range from 900 to 1600 m and mean annual rainfall range from 600 to 1000 mm. Establishment is by direct-seeding using a minimum tillage approach. Phenological characters, susceptibility to pests and diseases, and growth vigour are measured monthly, and dry-matter production annually in row-plot experiments. Seasonal yields of dry matter and nitrogen are also measured in companion sward experiments using a "best bet" sub-set of the collection.

A number of legumes which are well-adapted to the environments have been identified after three growing seasons and appear to have potential for a variety of uses in the local farming systems.

INTRODUCTION

Agriculture in the semi-arid midland regions of eastern Kenya is characterised by very low capital inputs, low outputs (even in good seasons) and a high frequency of seasons in which production of staple foods is insufficient for local needs. Rapid increases in rural population densities and in the intensity of cultivation, fuelwood harvesting and grazing have resulted in alarming rates of soil fertility depletion and soil erosion. While rainfall is the principal limiting resource, it is usually closely followed by soil fertility, hence the need to examine the role of legumes in the cereal-based farming systems of the regions as an alternative to the use of expensive nitrogen fertilizers.

FAO/GK/NORAD projects since 1974 (Wilton, 1976; Van Soest, 1986; Ibrahim, 1981; Chabeda, 1976) have made extensive collections of forage legumes within Kenya and evaluated them at four sites - Kitale, Kiboko, Katumani and Mtwapa along with some introduced material. However, much of the evaluation work is unpublished or is of a semi-quantitative nature, and the full potential of forage and browse legumes in Kenya's bimodal semi-arid areas remains little understood. In addition, many new species and accessions have become available from more recent plant collecting and evaluation activities in other parts of the world, and this material required testing in Kenya.

The objectives of the research programme reported here are:

1. to assemble an extensive seed collection of forage and browse species with potential adaptation to semi-arid areas of Kenya,

2. to assess the adaptation of this material in a series of experiments to a range of climatic conditions in the districts of Machakos and Kitui,

3. to select a nucleus of widely-adapted legumes that might fit into the varied farming systems in these districts, and to assist agronomists and animal production scientists in further evaluating this material in "on-farm" experimentation.

The work involves close collaboration between staff of the Kenya Government's Ministry of Agriculture and staff of the Australian Dryland Farming Project (ACIAR Project 8326) which is being implemented by the CSIRO Division of Tropical Crops and Pastures.

MATERIALS AND METHODS

Legumes

A total of 167 accessions from 23 genera are under evaluation. Details of ecotypes/species, Commonwealth of Australia Plant Introduction numbers, Kenya Introduction numbers, origin (where known) and project sites planted are contained in Appendix 1.

Field Sites

The experiments were undertaken at four fenced sites as follows:

1. *Katumani NDFRS*, altitude 1600 m, mean annual rainfall 717 mm, mean annual temperature 19.6°C, soil type: chromic luvisol, pH 6.5.

2. *Kiboko RRS*, 975 m, rf 595 mm, mean temperature 25.7°C, rhodic Feralsol, pH 5.8.

3. *Mua Hills*, 1650 m, rf 1179 mm, estimated mean temperature 19.0°C, red sandy earth, pH 7.0.

4. *Ithookwe (Kitui)*, 1160 m, rf 1080 mm, mean temperature 22.5°C, red sandy earth, pH 5.8.

Experimental Design and Layout

Row plot experiment. The experiments were laid in a randomised complete block design with 104 accessions and 3 replicates. Plots are 6.75 m^2 and consist of two rows each 2.25 m long and rows 1.5 m apart. Replicates run along the contour. One of each pair of rows received a single dressing of a basal fertilizer. The other row was unfertilized.

Sward experiments. For each season of planting, the experiments were arranged as randomised blocks with 20 accessions and three replicates. Individual plots were 16 m^2. Seed was not broadcast over the entire plot but distributed along disturbed rows 0.5 m apart. All plots received a basal fertilizer dressing at establishment.

Seed Preparation

Row plot experiments. Seed viability was determined by germinating scarified seed on moist filter pads in petri dishes. Approximately 50% of all seeds/plot were scarified by sandpaper or scalpel. Inoculation with the requisite rhizobia in a gum arabic/distilled water solution was made a few days prior to planting. Inoculated seed was kept under refrigeration.

Sward experiments. Seed preparation was similar to that for row plots except that 100% seed scarification was attempted, and the seeding rate was adjusted to give similar numbers of viable seeds per plot (Table 2).

Land Preparation, Sowing and Seedling Establishment

Land preparation was minimal except for Ithookwe (site 4) which was ploughed just prior to planting. Vegetation was cut back and burned off during the dry season and line rows pegged out. A small chisel plough attached to a two-wheel Honda mini-tractor marked a 4 cm deep furrow along each planting row. At the onset of rains, when weed seedlings had emerged, the furrows were dusted with Aldrin 2.5% @ 20 kg/ha. Legume seed was then hand-sown, lightly covered and firmed with soil. Two days later or just prior to legume germination the planted rows were sprayed with Roundup herbicide 2 l/ha using a knapsack sprayer fitted with a fan nozzle. Subsequent row weeding was done by hand or with a rope wick containing Roundup.

Data Collection/Harvesting

Row plot experiments (Table 1). Agronomic and phenological characters recorded monthly from the second month after sowing included plant population and development (vegetative, flowering and seeding), height, date of anesthesis, insect and disease incidence and a visual bulk rating on a one-five scale. In early October 1986, after 11 months of uninhibited growth, a measured length of average plant material in each row plot was cut at 5 cm above ground level (5 cm from the crown for trailing legumes), oven dried at 60°C and weighed. Sample weight was converted to yield (kg/ha) by the formula

$$10 \; \frac{(\text{Sample wt})}{(\text{cut length} \times 1.5)}.$$

Sample experiments. Plant measurements similar to those given above were made except that for visual bulk ratings. Harvesting entailed cutting two randomised 1 m^2 quadrats 5 cm above ground level from each plot three times per year. The first harvest was in late January, 1986 (end of short rains), the second in early June, 1986 (end of long rains) and the third in late September, 1986 (end of dry season). The latter harvest also included measurements of regrowth from the first harvest. Cut material was oven-dried at 60°C, weighed and subsampled for later N analysis.

Fertilizer Applications

Two weeks after legume seedling emergence a basal fertilizer was hand broadcast along one row of the row plots to a width of 1.5 m and evenly broadcast over the swards. Rates in kg/ha were: triple superphosphate 200, muriate of potash 41.7, dolomite 250, manganese sulphate 15, borax, zinc sulphate and copper sulphate 10, respectively and sodium molybdate 0.36. The swards received the same mixture broadcast over the entire plot.

Methodology for Experiments with Leucaena Accessions

At Katumani, a collection of Mexican high altitude *Leucaena* accessions is being tested quantitatively against a suite of commercial cultivars including cv Cunningham, cv Peru and K8. Adaptation is progressively monitored throughout each year by measuring shoot extension growth relative to soil moisture content and air temperatures. Destructive harvests are made twice and four times per year for wood, stem and leaf yield.

RESULTS

Row Plot Experiments

Data from 16 accessions which performed well at Site 1 (Katumani), Site 2 (Kiboko) or both sites are presented in Table 1. Of the annuals, the short season *Macrotyloma africanum* with densely twining fine stems, had high resistance to insect and disease, good seed production and an excellent seedling regenerative capacity. Another trailing legume *Vigna unguiculata* CI60452 was more strongly persistent at both sites than other entries from that genus. *Alysicarpus rugosus* established well and had the highest edible dry matter (EDM) (1938 kg/ha) at the end of the evaluation period at Site 1. The two *Stylosanthes hamata* lines, cv Verano and K14363, are morphologically similar, but the latter persisted later into the dry season. Both accessions and the late flowering *S. humilis* are particularly susceptible to termites. *Lablab purpureus* cv Rongai grew vigorously at both sites and gave high visual bulk ratings. It flowered profusely, but seed production was reduced by the depradations of flower-eating beetles *Mylabris* and Coryna sp.

The selected perennial legumes (Table 1) have persisted strongly at Site 1 but only *Desmanthus virgatus, S. scabra* cv Fitzroy cv Seca and *S. guianensis* Alupe 'C' survived the, harsher environment at Site 2. These *Stylosanthes* accessions yielded >4 tonnes EDM/ha at Katumani and appear particularly well adapted at that site. The semi-erect shrub legume *Desmanthus virgatus* K14456 was slow to establish but showed promise later in the experiment at both sites. *Neonotonia wightii* was also slow to establish but grew vigorously after the second season. *Cassia rotundifolia* cv Wynn flowered very early and continued to produce seed throughout the year. It has persisted strongly at Site 1

Table 1. Fiel data from 16 selected forage legumes at two sites (Est. 1.11.85).

Accessions	PBR Site 1	Days	PBR Site 2	Days	Max. ht (cms) Site 1	Site 2	Anesthesis (days) Site 1	Site 2	Seed Production Site 1	Site 2	Pet disease 1	2	1	2	EDM yield (kg/ha) Site 1	Site 2
Alysicarpus K14384	3.6	180	3.0	120	30	20	80	140	2	2	0	0	0	0	938	-
Lablab purpureus cv Rongai	4.3	90	5.0	60	55	60	110	200	2	2	2	0	0	0	-	-
Macrotyloma africanum K14348	3.5	90	3.2	90	10	15	55	80	3	2	0	0	0	0	-	-
Stylosanthes hamata cv Verano	5.0	210	4.0	180	20	25	60	60	3	3	3	0	0	0	678	-
Stylosanthes hamata K14365	4.8	210	4.3	210	15	15	60	60	3	3	3	1	0	0	820	-
Stylosanthes humilis K14368	4.8	210	4.1	210	10	15	150	170	3	3	2	0	2	0	362	-
Vigna unguiculata CPI 60452	3.2	150	4.0	60	15	25	60	60	2	2	1	0	1	0	-	-
Cassia rotundifolia cv Wynn.	5.0	210	3.0	180	20	20	50	30	3	2	1	1	0	0	851	-
Desmanthus virgatus K14456	3.1	300	2.6	180	25	25	120	140	2	2	1	0	0	0	720	-
Desmodium intortum cv Greenleaf	3.5	240	1.6	90	40	15	210	-	2	0	2	0	0	0	1198	-
Neonotonia wightii K2366	4.8	210	3.0	210	30	20	200	210	3	1	1	1	0	0	1551	309
Stylosanthes fruticosa K14426	4.5	210	2.6	270	25	15	110	90	3	2	1	0	0	0	2015	415
Stylosanthes guianensis cv Graham	4.3	210	3.6	210	30	20	100	60	3	3	1	0	0	0	1407	551
Stylosanthes guianensis Alupe 'C'	5.0	210	4.5	210	45	40	(90)	180	2	1	1	1	0	0	4175	
Stylosanthes scabra cv Fitzroy	5.0	210	4.0	210	45	35	100	90	3	3	1	0	0	0	4112	
Stylosanthes scabra cv Seca	5.0	210	4.0	210	60	50	100	90	3	3	1	0	0	0	4127	

Site 1: Katumani NDFRS

Site 2: Kiboko R.R. Station

RPBR : Peak Bulk Rating

Seed Production: 0=nil, 3=good

Pest/Disease: 0-1, 3=severe

EDM yield: at 11 months.

	1985						1986					
Rainfall(mm)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept
Site 1	85	57	137	63	-	43	163	100	7	-	-	-
Site 2												

- Not available

Table 2. List of accessions used in sward studies.

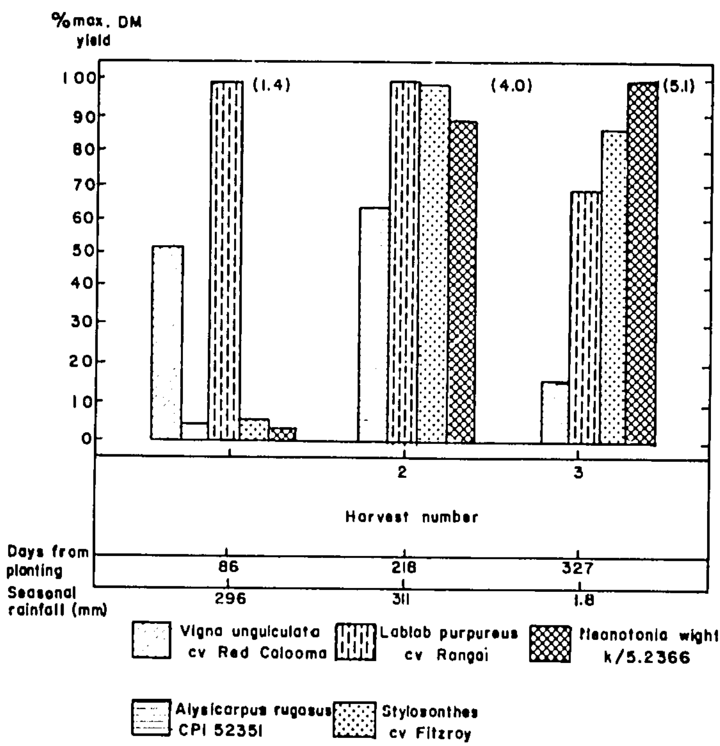
	Present in planting number				
	1	2	3	4	Mean sowing rate kg/ha
Alysicarpus rugosus CPI 52351	*	*	*	*	4.3
Alysicarpus rugosus CPI 30034			*		4.3
Cassia rotundifolia Q10057	*				5.2
Cassia rotundifolia cv Wynn		*	*	*	5.2
Centrosema pascuorum cv Cavalade	*	*	*		26.1
Centrosema pascuorum CPI 65950			*		26.1
Centrosema schottii CPI 82271	*	*			26.1
Centrosema schottii CPI 76010	*	*			26.1
Centrosema virginianum CQ 2748			*	*	26.1
Clitoria ternatea CPI 48337	*	*			43.8
Clitoria ternatea CPI 47187	*	*	*	*	43.8
Clitoria ternatea CPI 49963	*	*	*	*	43.8
Desmanthus virgatus CPI 40071	*	*	*	*	9.8
Desmodium intortum cv Greenleaf	*	*	*	*	7.8
Dolichos Lablab K1002		*	*	*	89.0
Lablab purpureus cv Rongai	*	*	*	*	9.5
Lotononis bainesii cv Miles	*				6.1
Macrotyloma africanum CPI 24972		*	*	*	6.1
Macrotyloma africanum CPI 60207		*	*	*	6.1
Macrotyloma daltonii CPI 60303		*	*		16.2
Macroptilium atropurpureum cv Siratro	*	*	*	*	9.1
Mucuna sp				*	160.5
Neonotonia wightii K75.2366	*	*	*	*	6.8
Rhyncosia minima CPI 52713	*	*			10.8
Rhyncosia malacophylla K18176			*	*	10.8
Stylosanthes capitata CPI 55843	*				7.1
Stylosanthes guianensis cv Graham	*	*			7.1
Stylosanthes guianensis cv Cook			*	*	7.1
Stylosanthes hamata cv Verano	*	*	*	*	7.1
Stylosanthes scabra cv Fitzroy	*	*	*	*	7.1
Stylosanthes scabra cv Seca	*				7.1
Stylosanthes fruticosa CPI 41219A	*	*	*	*	7.1
Vigna trilobata CPI 13671	*				10.8
Vigna unguiculata cv M66		*	*	*	82.4
Vigna unguiculata cv Red Caloona	*	*	*		82.4

with useful seasonal seedling regeneration. *Desmodium intortum* cv Greenleaf is susceptible to termites and while quite vigorous during seasonal rains only just survived the long dry season at Site 1.

Sward Experiments

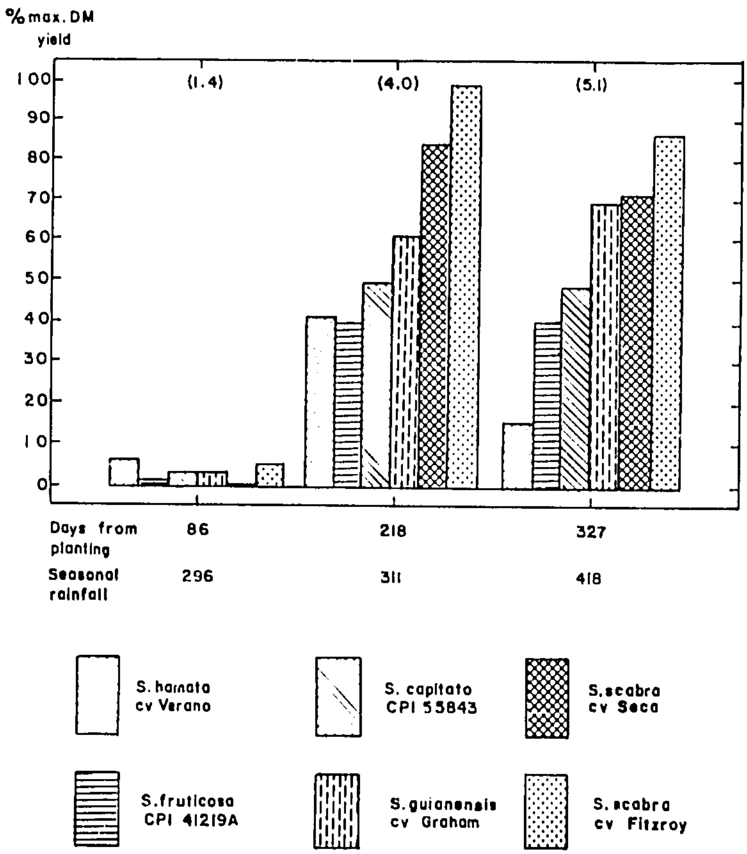
The most complete data set currently available is for the first planting at the Maruba site. The pattern of dry-matter accumulation varied greatly between accessions as shown in Figure 1a. Single-season grain legumes such as *Vigna unguiculata* cv Red Caloona produced modest levels of dry matter after the first rainy season (see Harvest 1) but none thereafter. The dual purpose (forage/grain) legumes, such as *Lablab purpureus* (cv Rongai) were the most productive after the first and second rainy seasons (see Harvests 1 and 2) but declined thereafter (see Harvest 3). Maximum for the 18 other accessions tested was only 11% of the biomass produced by *lablab purpureus*. Legumes such as *Alysicarpus rugosus, Stylosanthes scabra* and *Neonotonia wightii* needed two rainy seasons to reach the production levels of an accession like *Lablab purpureus*. Thereafter, strong perennial species such as *S. scabra* and *N. wightii* had a clear advantage whilst annuals such as *A. rugosus* declined over the long dry season.

Figure 1a. Relative dry-matter yield (expressed as a percentage of the maximum dry-matter yield) for five legume swards grown at Maruba, Kenya. Swards were planted on 30-10-85 and the third harvest was taken 327 days later on 22-9-86. Absolute dry-matter yield in tonnes ha^{-1} is shown in parentheses for each harvest.



The first sward plantings at Katumani also provided an opportunity to compare the productivity of a relatively large number of *Stylosanthes* species under the cool dry conditions of the midlands of eastern Kenya. In all, six accessions from five species were included in this planting as shown in Figure 1b. None of the long season annuals, biennial or perennial species produced any significant levels of biomass by the end of the first season. After this time, however, the *Stylos* were all relatively productive with the *S. scabra* cultivars, Fitzroy and Seca the most outstanding (3.4 to 4.4 tonnes ha^{-1}), followed by *S. guianensis* cv Graham (2.5 to 3.5 tonnes ha^{-1}). The least adapted *Stylo* to this region was *S. hamata* cv Verano.

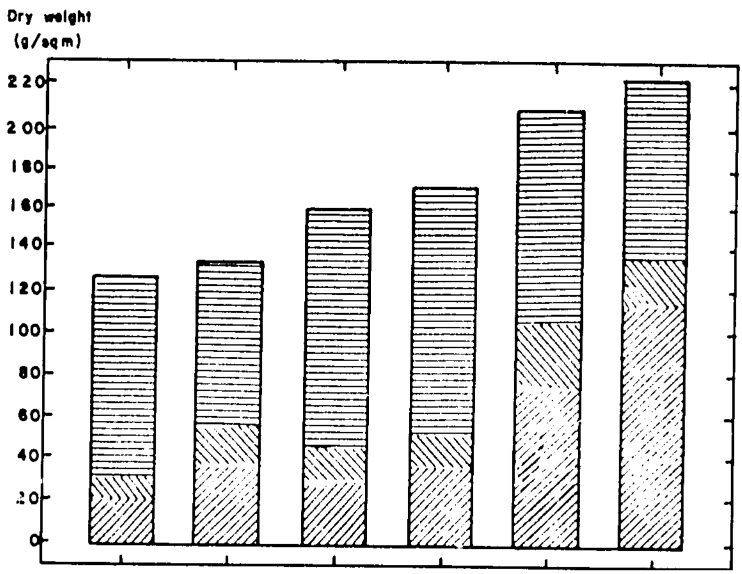
Figure 1b. **Relative dry-matter yield (expressed as a percentage of the maximum for the particular harvest) for six *Stylosanthes* accessions grown at Maresha, Kenya. Other details as Figure 1a.**



Leucaena Experiment

The first two destructive harvests from the *Leucaena* experiment have now been completed. Dry matter data is shown in Figure 2. From the preliminary data, the cultivar Peru appears to be the most productive in terms of leaf production, whilst *L. diversifolia* CPI 33820 was producing the largest amount of wood.

Figure 2. Dry weight data from first cut of Leucaena accessions. Planted: 4/4/86; First cut: 29/12/86.



DISCUSSION

The potential role of forage and browse legumes in the semi-arid midlands of Kenya is in smallholder farming systems. Legumes could conceivably be used as inter-crops/alley-crops with cereals, in erosion control, in terrace bank stabilisation, in the improvement of degraded, non-productive grassland or as simple cut-and-carry fodder banks. The range of growth habit and persistence within the plant material being evaluated extends from the short twining annual *Macrotyloma africanum* to the small perennial tree *Leucaena*. Further experimentation (preferably on farms) is required to sort out the respective roles of material available, but the results from the experiments described here indicate that a good range of well-adapted leguminous material is now available.

Materials recommended for further testing in more favourable environments in the region (as characterised by Site 1 at Katumani NDFRS) are *Cassia rotundifolia* cv Wynn, *Desmanthus virgatus* K14456, *Lablab purpureus* cv Rongai, *Macrotyloma africanum* K14348, *Neonotonia wightii* K2366, *Stylosanthes guianensis* 'Alupe C' and *Stylo scabra* cv Fitzroy and 'Seca'. At less favourable sites (similar to Kiboko, Site 2) this list is reduced to *Desmanthus virgatus* and *Stylosanthes scabra*.

With the expansion of evaluation work to two other sites (3 and 4) and the inclusion of more plant material - from the Kenya Plant Quarantine Station at Muguga, from a small, indigenous plant collection and from further introduction from CSIRO, Queensland - the range of accessions being tested has recently increased. While evaluation of the following lines *Aeschynomene americana* cv Glenn, *Cassia pilosa* CPI 57503, *Lotononis angolensis* CPI 62202, *Macrotyloma axillare* cv Archer, *Macrotyloma* sp. (indigenous), *Mucuna pruriens* aff., *Rhyncosia malacophylla* (Synon. *sennarensis)*, *Rhyncosia totta* and *Stylo guianensis* cv Cook is incomplete, they all show considerable promise.

The critical role of legume seed nurseries cannot be over-emphasised. Once key lines have been identified, seed requests from research stations and research or extension officers cannot be met if supply is a constraint. The nurseries should be established in areas where demands on irrigation, man-power and supervision are easily met. Work is underway this season to produce experimental quantities of seed of the promising accessions noted above.

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Appendix 1. Legume-evaluation: Accession list.

	CPI	K	Origin	Site
Aeschynomene americana	91145	19712	Mexico	1
Aeschynomene americana	cv Glenn	19897	Mexico	1,4
Aeschynomene elegans	37552	19714	Argentina	1
Aeschynomene falcata	cv Bargoo	19715	Paraguay	1,4
Aeschynomene villosa	37235	19716	Mexico	1
Aeschynomene villosa	91113	19720	Mexico	1
Alysicarpus glumaceus	52366	14449	Madagascar	1,2
Alysicarpus hamosus	94491	14374	Oman	1,2
Alysicarpus longifolius	94490	14376	Oman	1,2
Alysicarpus monilifer	52343	14377	Madagascar	1,2
Alysicarpus rugosus	30034	14382	India	1,2,3,4
Alysicarpus rugosus	52348	14383	Zimbabwe	1
Alysicarpus rugosus	52351	14384	Malawi	1,2,3,4
Alysicarpus rugosus	76980	14447	Zambia	1
Alysicarpus rugosus	94489	14395	Ethiopia	1,2
Alysicarpus rugosus	-	(50)	Kenya	1,2
Alysicarpus vaginalis	34149	14386	Nicaragua	1,2,4
Arachis monticola	CQ990	14388	-	1
Arachis pintoi	58113	14416	Brazil	1
Cassia pilosa	57503	14451	Venezuela	1,2,4
Cassia rotundifolia	86172	19724	Mexico	1
Cassia rotundifolia	86178	19725	Mexico	1
Cassia rotundifolia	Q10057	14450	Brazil	1
Cassia rotundifolia	cv. Wynn	18177	-	1,2,3,4
Centrosema acutifolium	92874	14391	Brazil	1,2
Centrosema acutifolium	94303	14390	Colombia	1
Centrosema brasilianus	55698	14417	Brazil	1,2,4
Centrosema macrocarpum aff	78358	20170	Brazil	4
Centrosema pascuorum	65950	14392	Equador	1,2,3,4
Centrosema pascuorum	cv Cavalcade	14418	-	1,2,3,4
Centrosema plumieri	60477	14393	Brazil	1,2
Centrosema plumieri	82269	14394	Cuba	1,2
Centrosema pubescens	43197	20171	Colombia	4
Centrosema pubescens	46543	14395	Guatemala	1,2
Centrosema pubescens	58575	20172	Colombia	4
Centrosema pubescens	63895	14396	Brazil	1,2,4
Centrosema pubescens	79630	20173	-	4
Centrosema pubescens	92721	14397	Colombia	1
Centrosema pubescens	cv Belalto	14332	-	1,2
Centrosema pubescens	cv Centro	14419	-	1,2
Centrosema schottii	76010	14398	Mexico	1,2,3
Centrosema schottii	82271	14445	Cuba	1,2,3
Centrosema virginianum	CQ2748	14399	-	1,2,3,4
Centrosema virginianum	91142	14400	Mexico	1,2,3,4
Clitoria ternatea	47187	14402	Sudan	1,2,3,4
Clitoria ternatea	48337	14403	Tanzania	1,2,3,4
Clitoria ternatea	49963	14404	-	1,2,3,4
Desmanthus bicocnutus	91162	14438	Mexico	1
Desmanthus subulatus	90857	14406	Mexico	1
Desmanthus virgatus	40071	14456	Brazil	1,2,3,4
Desmanthus virgatus	55719	14407	Venezuela	1,2
Desmanthus virgatus	65947	14405	Equador	1,2
Desmanthus virgatus	78373	14408	Argentina	1,2
Desmanthus virgatus	83570	14409	Brazil	1,2,4

	CPI	K	Origin	Site
Desmanthus virgatus	84508	14410	Mexico	1,2
Desmanthus virgatus	85178	14411	Mexico	1,2
Desmanthus virgatus	90750	14412	Mexico	1,2
Desmanthus virgatus	91146	14413	Mexico	1,2
Desmanthus virgatus	91326	14414	Mexico	1,2,4
Desmanthus virgatus	92818	14415	Belize	1,2,4
Desmodium dichotosum	47186	-	-	1,2
Desmodium intortum	cv Greenleaf	14455	-	1,2,3,4
Desmodium intortum	91135	14338	Mexico	1,2
Desmodium oringlei	37232	14334	Mexico	1,2
Desmodium prostratum aff	91232	14336	Mexico	1,2
Desmodium setigeruam	52431	14340	Malawi	1,2
Desmodium subsericeum	78402	14335	Argentina	1,2
Desmodium wigginsii	90418	14337	U.S.A.	1,2
Desmodium sp. D	91166	14453	Mexico	1
Desmodium sp. D	91212	14333	Mexico	1,2
Dolichos sp.	24973	14452	Zimbabwe	1,2,4
Dolichos sericeus aff	-	(128)	Kenya	1,4
Lablab purpureus	30702	14466	Burma	1
Lablab purpureus	41222	14341	Burma	1,2
Lablab purpureus	cv Highworth	14463	-	1,2
Lablab purpureus	cv Rongai	14420	Kenya	1,2,3,4
Lablab purpureus	-	1002	Kenya	1,2,3,4
Lespedeza striata	cv Kaloe	19899	U.S.A.	1,4
Lotononis angolensis	62202	14435	-	1,2,4
Lotononis bainesii	cv Miles	14421	-	1,2,4
Macroptilium atropurpureum	84989	14343	Mexico	1,4
Macroptilium atropurpureum	84999	14344	Mexico	1,2
Macroptilium atropurpureum	90748	14468	Mexico	1,4
Macroptilium atropurpureum	90776	14469	Mexico	1,4
Macroptilium atropurpureum	90821	14465	Mexico	1
Macroptilium atropurpureum	cv Siratro	14461	Mexico	1,2,3,4
Macroptilium heterophyllum	90448	14345	Mexico	1,4
Macroptilium heterophyllum	91144	14467	Mexico	1
Macroptilium heterophyllum	91222	14346	Mexico	1
Macroptilium lathyroides	cv Murray	14464	India	1,2
Macroptilium longipendunculatum	55751	14422	Brazil	1,2
Macroptilium martii	49780	14347	Brazil	1,2,4
Macroptilium prostrata	78450	14342	Argentina	1
Macrotyloma africanum	24972	14348	Zambia	1,2,3,4
Macrotyloma africanum	60207	14349	Zambia	1,2,3,4
Macrotyloma axillare	cv Archer	14462	-	1,4
Macrotyloma daltonii	60303	14350	Namibia	1,2,3,4
Macrotyloma daltonii	94496	14351	-	1
Macrotyloma uniflorum	cv Leichardt	14460	-	1,2
Macrotyloma sp.	-	(129)	Kenya	1,4
Medicago rugosa	cv Paraponto	19905	-	1,4
Medicago rugosa	cv Sapo Gama	19906	-	1,4
Medicago sativa	cv H. River	19900	-	1,4
Medicago scutella	cv Sava	19907	-	1,4
Medicago trunculata	cv Jemalong	19908	Australia	1,4
Mucuna pruriens aff	-	(119)	Kenya	1,4
Neonotonia wightii	-	2366(67)	Kenya	1,2,3,4
Neonotonia wightii	-	(35)	Kenya	1,2,3,4

	CPI	K	Origin	Site
Neonotonia wightii	-	(150)	Kenya	1,4
Rhyncosia densiflora	52690	14353	Tanzania	1,2
Rhyncosia edulis	52127	14352	Paraguay	1,2
Rhyncosia malacophylla	-	18176	Tanzania	1,2,3,4
Rhyncosia minima	52713	14355	Tanzania	1,2,3
Rhyncosia minima	78473	14356	Argentina	1
Rhyncosia minima	84953	14357	Mexico	1,2
Rhyncosia minima aff	-	(14)	Kenya	1,2
Rhyncosia minima aff	-	(41)	Kenya	1,2
Rhyncosia minima aff	-	(45)	Kenya	1,2
Rhyncosia totta	52742	14358	Zambia	1,4
Stylosanthes capitata	55843	14459	Brazil	1,2,4
Stylosanthes fruticosa	41219A	14426	Sudan	1,2,3,4
Stylosanthes fruticosa	-	(33)	Kenya	1,2
Stylosanthes guianensis	79637	14364	Brazil	1,2,4
Stylosanthes guianensis	-	Alupe C	-	1,2,4
Stylosanthes guianensis	-	Alupe I	-	1,2
Stylosanthes guianensis	cv Cook	18189	Colombia	1,2,3,4
Stylosanthes guianensis	cv Graham	14427	Bolivia	1,2,3,4
Stylosanthes guianensis	cv Oxley	19901	Argentina	1,4
Stylosanthes hamata	49080	14365	Colombia	1,2
Stylosanthes hamata	70522	14366	U.S.A.	1,2
Stylosanthes hamata	73507	14367	Antigua	1,2
Stylosanthes hamata	cv Verano	14428	Venezuela	1,2,3,4
Stylosanthes humilis	61674	14368	Venezuela	1,2
Stylosanthes humilis	cv Greenvale	14429	-	1,2
Stylosanthes scabra	55856	18190	Brazil	1,2
Stylosanthes scabra	cv Fitzroy	14431	-	1,2,3,4
Stylosanthes scabra	cv Seca	14430	-	1,2,3,4
Stylosanthes scabra	-	8115	-	1,2
Stylosanthes scabra	-	8111	-	1,2
Stylosanthes scabra	-	82105	-	1,2
Stylosanthes subsericea	38605	14457	Guatemala	1,2
Stylosanthes sympodialis	67704(B)	14369	Equador	1,2
Stylosanthes viscosa	34904	14371	Brazil	1,2
Stylosanthes sp.	85895	14359	Mexico	1,2
Stylosanthes sp.	85899	14360	Mexico	1,2
Stylosanthes sp.	86137	14361	Mexico	1,2
Stylosanthes sp.	87469	14458	Mexico	1,2
Stylosanthes sp.	87479	14362	Mexico	1,2
Stylosanthes sp.	87484	14423	Mexico	1,2
Stylosanthes sp.	87485	14424	Mexico	1,2
Stylosanthes sp.	87487	14425	Mexico	1,2
Stylosanthes sp.	91138	14363	Mexico	1,2
Trifolium repens	cv Haifa	19902	Israel	1,4
Trifolium sp.	-	(26)	Kenya	1,3
Vigna ambacensis	47188	14433	Sudan	1,2
Vigna frutescens	-	(126)	Kenya	1
Vigna luteola	ILCA 113	18172	Belize	1,4
Vigna oblongifolia	60430	14372	-	1,2
Vigna praecox	-	(130)	Kenya	4
Vigna trilobata	13671	14434	-	1,2,3
Vigna unguiculata	60442	14313	-	1,2
Vigna unguiculata	60452		Kenya	1,2,4
Vigna unguiculata	cv Red Caloona	14436	-	1,2,3,4

	CPI	K	Origin	Site
Vigna unguiculata	-	M66	Kenya	1,2,3,4
Vigna vexillata	-	(122)	Kenya	1,4
Voandzeia subterranea	-	18174	Mali	4
Zornia sp.	-	(123)	Kenya	1

CHARACTERISATION AND PRELIMINARY EVALUATION OF ACCESSIONS OF *ZORNIA* SPECIES FROM THE ILCA COLLECTION

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Abstract

The genus, Zornia *has a tropical distribution mainly in America and Africa. A collection of* Zornia *species is used to provide natural grazing and hay during different seasons.*

The genus has maintained its taxonomic notoriety. The significance of classification of the species in this genus would possibly be in the application of various groupings to agronomic problems, particularly selection and/or breeding for specific purposes.

As a guide to the understanding of the range of variation available in the Zornia *accessions at ILCA, a study was made on the plants already growing at Soddo, Ethiopia, based on morphological and agronomic characters. Analysis of the collected data revealed that with the use of morphological characters, it was possible to obtain groupings belonging to particular species as exemplified by* Zornia setosa, Z. glochidiata, Z. glabra *and* Z. latifolia. *Based on agronomic characters a different pattern was obtained, but this narrowed the collection into two major groups. One group was characterised by prostrate to decumbent accessions while the other group comprised accessions which ranged from decumbent to erect in their growth forms. Other smaller groups with particular agronomic attributes could also be identified.*

It seemed imperative, however, that further studies involving more attributes than those used here would provide more systematic groupings of accessions with succinct characteristics.

INTRODUCTION

The genus *Zornia* is indigenous to savannas and similar areas in tropical and subtropical regions of the world (Mohlenbrock, 1961; McIvor and Bray, 1983). The number of species in this genus is variable but commonly estimated to be around 80 and distributed predominantly in America and Africa.

Some *Zornia* species (Bogdan, 1977) are of importance in providing natural grazing and hay, especially in Brazil and the neighbouring countries and also in the drier parts of West Africa. Species like *Z. glochidiata* (synonym *Z. diphylla*) provides some scant forage during the wet season and early in the season but does not survive long into the dry season (Skerman, 1977).

The genebank at the International Livestock Centre for Africa (ILCA) currently holds at least 234 accessions of *Zornia* species some of which were grown for seed production and agronomic evaluation during mid-1985 at Soddo in Sidamo, Ethiopia. In order to provide some quick information about these collections, a study of these accessions was superimposed on the existing evaluation programme. Using 22 attributes on 161 accessions of *Zornia* species data were collected on field-grown plants that had been growing for just over one year. The 22 attributes comprised both morphological and agronomic characters (Table 1) whose choice was partially based on taxonomic character descriptions of *Zornia* species (Mohlenbrock, 1961) and some of the forage evaluation characters used at ILCA. The purpose of this work was to try and group these accessions on the basis of their similarities and dissimilarities using both morphological and agronomic characters. This was to assist in picking out closely related accessions and also to obtain those accessions of good agronomic characters that could be subjected to further evaluation while awaiting the results from the ongoing evaluation trial.

The collection data were classified using principal component analysis (PCA), cluster analysis (CA) and K-means clustering.

Table 1. Codes for the characters (descriptors and descriptor states) recorded on the *Zornia* sp. growing at Soddo, Ethiopia.

1. Number of leaflets per leaf: 1 = 2 leaflets
   2 = 4 leaflets

2. Flower size: 1 = flowers shorter than the bracts
   2 = flowers longer than or equal to the bracts

3. Shape of the leaflets of the lowest leaves:
   1 = linear; 2 = filiform; 3 = lanceolate;
   4 = ovate; 5 = elliptic; 6 = elliptic/lanceolate; 7 = oblanceolate; 8 = obovate

4. Size of the lowest leaflets: 1 = leaflets more than twice as long as broad.
   2 = leaflets not more than twice as long as broad.

5. Shape of upper leaflets: 1 = linear;
   2 = filiform; 3 = lanceolate;
   4 = ovate; 5 = elliptic;
   6 = elliptic/lanceolate; 7 = oblanceolate;
   8 = obovate

6. Flower colour:
   1 = corolla yellow with no red marks
   2 = corolla yellow with few red marks
   3 = corolla yellow with many red marks
   4 = corolla red

7. Flower (corolla) size: 1 = very small;
   2 = small; 3 = small-medium; 4 = medium;
   5 = medium-large; 6 = large.

8. Plant growth form: 1 = creeping; 2 = prostrate; 3 = semi-prostrate; 4 = decumbent; 5 = semi-erect; 6 = semi-erect/erect; 7 = erect

9. Bract and leaf pubescence: 1 = glabrous; 2 = pilose

10. Colour of the bracts: 1 = green; 2 = green with yellow marks; 3 = green with red marks; 4 = purple

11. Internode length: 1 = very short; 2 = short; 3 = medium; 4 = long

12. Internode thickness: 1 = very slender; 2 = slender; 3 = medium; 4 = thick

13. Inflorescence length of lowest inflorescence: 1 = very short; 2 = short; 3 = medium; 4 = long

14. Spread of the bracts on the inflorescence: 1 = very sparse; 2 = sparse; 3 = medium; 4 = large

15. Bract size: 1 = very small; 2 = small; 3 = medium; 4 = large

16. Leafiness: 1 = negligible; 2 = very poor; 3 = poor; 4 = fair; 5 = good; 6 = very good

17. Plot cover: 1 = negligible; 2 = very poor; 3 = poor: 4 = fair; 5 = good; 6 = very good

18. Inflorescence density: 1 = negligible; 2 = very poor; 3 = poor; 4 = fair; 5 = high; 6 = very high

19. Branching intensity: 1 = negligible; 2 = very poor; 3 = poor; 4 = fair; 5 = high; 6 = very high

20. Vigour = 1 = negligible; 2 = very poor; 3 = poor; 4 = fair; 5 = good; 6 = very good

21. Productivity: 1 = negligible; 2 = very low; 3 = low; 4 = medium; 5 = high; 6 = very high

22. Adaptability: 1 = negligible; 2 = very poor; 3 = poor; 4 = fair; 5 = good; 6 = very good

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METHODOLOGY

A total of 161 *Zornia* accessions which were growing at Soddo in Sidamo Province of Ethiopia were observed for characterisation and preliminary evaluation. Soddo is at an elevation of 1850 m with acid Nitosols of pH 5.5 to 6.0. Rainfall is above 700 mm per year while the minimum and maximum temperatures are 12.6^{o}C and 24.5^{o}C respectively. The total length of the growing season is 245 days.

Each accession has been planted on unreplicated raised plots each containing six plants. The plot size was 2 m by 1.5 m with 75 cm pathways across the slope and 1 m pathways or drains down the slope.

Twenty-two characters - morphological and agronomic - that could be recorded at the time were selected based on their taxonomic applicability. Each of the 22 characters was recorded once for each accession.

An HP 3000 computer and BMDP software were used for analysis of the collected data. For PCA the BMDP4M program was employed while the CA used the BMDP2M program to produce the vertical and horizontal dendrograms. The K-means clustering used BMDPKM program (Engelman, 1980; Frane and Hill, 1974).

Only components with Eigenvalues greater than unity were retained in the principal component analysis, and they were rotated by the Varimax procedure to aid interpretation.

The BMDPKM program for K-means clustering used the hierarchical agglomerative method (Engelman, 1980). All data were standardised before clustering. The BMDPKM program iteratively reallocates cases into clusters until each case is in the cluster whose centre is closest to the case. This procedure is followed for each number of clusters specified. In this study the specified clusters were 8, 10 and 12. The criterion of clustering was to minimise the maximum distance of a case from the centre of the cluster to which the case belonged. The word "case" here is synonymous to "accession".

In all the above analyses the characters were considered under morphological, agronomic and morphological-agronomic categories.

RESULTS

Principal Component Analysis

Before carrying out principal component analysis it was necessary to consider the correlation matrix for the characters under study. There existed a number of high correlations among the characters which confirmed the justification for carrying out principal component analysis on the data (Tables 2, 3 and 4). The level of significance at 5% and 1% were respectively >0.15 and >0.211 for morphological characters; >0.156 and >0.204 for agronomic characters; and >0.214 for morphological-agronomic (all) characters.

On application of the principal component analysis to the data, four factors (components) were found to have eigenvalues greater than unit for morphological characters, three for agronomic characters and four for morphological-agronomic

Table 2. Correlation matrix for morphological characters in Zornia sp.

		NLEAFPLF 3	FLOWERSZ 4	SHAPELL 5	SIZELL 7	FLOWERCO 8	FLOWERSZ 9	BRACTSCO 12	ININDEL 13	ININDETH 14	INFLLENG 15	SPBRINFL 16	BRACTSZE 17
NLEAFPLF	3	1.000											
FLOWERSZ	4	0.064	1.000										
SHAPELL	5	0.742**	0.052	1.000									
SIZELL	7	0.661**	0.001	0.765**	1.000								
FLOWERCO	8	-0.699**	-0.093	-0.393**	-0.388**	1.000							
FLOWERSZ	9	-0.096	0.126	-0.197*	-0.184*	-0.245**	1.000						
BRACTSCO	12	-0.486**	-0.048	-0.431**	-0.461**	0.277**	0.259**	1.000					
ININDEL	13	-0.266**	0.154	-0.096	-0.063	0.155	-0.018	0.109	1.000				
ININDETH	14	-0.180**	0.090	-0.090	-0.002	-0.033	0.302**	-0.009	0.302**	1.000			
INFLLENG	15	-0.306**	-0.173*	-0.046	-0.064	0.308**	-0.113	-0.040	0.374**	0.142	1.000		
SPBRINFL	16	-0.202**	-0.150	-0.315**	-0.317**	-0.079	0.514**	0.257**	-0.147	0.023	-0.016	1.000	
BRACTSZE	17	0.146	-0.286**	-0.006	-0.011	-0.310**	0.533**	0.074	-0.291**	0.101	-0.045	0.643*	1.000

Level of significance: 5% : >0.161 (*)

1% : >0.211 (**)

Table 3. Correlation matrix for agronomic characters in Zornia sp.

		PLGRFORM 10	LEAFNESS 18	PLOTCOVR 19	INFLDENS 20	BRANDENS 21	VIGOUR 22	PRODUCTV 23	ADAPTBTY 24
PLGRFORM	10	1.000							
LEAFNESS	18	-.279**	1.000						
PLOTCOVR	19	.140	.453**	1.000					
INFLDENS	10	.319**	.086	.659**	1.000				
BRANDENS	21	.285**	.264**	.746**	.798**	1.000			
VIGOUR	22	.202**	.354**	.587**	.458**	.501**	1.000		
PRODUCTV	23	.259**	.403**	.785**	.676**	.690**	.701**	1.000	
ADAPTBTY	24	.309**	.397**	.767**	.655**	.700**	.724**	.940**	1.000

Level of significance: 5% : >0.156 (*)
1% : >0.204(**)

Table 4. Correlation matrix for morphological-agronomic characters in Zornia sp.

		FLOWERSZ 4	SHAPELL 5	SIZEUL 7	FLOWERSZ 9	PLGRFORM 10	BRACTSCO 12	BRACTSZE 17	LEAFNESS 18	PLOTCOVR 19	INFLDENS 20	BRANDENS 21	VIGOUR 22	PRODCTV 23	ADAPTBTY 24
FLOWERSZ	4	1.000													
SHAPELL	5	.069	1.000												
SIZEUL	7	-.007	.551**	1.000											
FLOWERSZ	9	.154	-.182*	-.160	1.000										
PLGRFORM	10	.233**	-.054	-.168*	.257**	1.000									
BRACTSCO	12	.025	-.114	-.212*	.281**	.421**	1.000								
BRACTSZE	17	-.399**	-.210*	-.177*	.587	.057	.181*	1.000							
LEAFNESS	18	.022	-.095	-.039	.183*	-.314**	-.191*	.196*	1.000						
PLOTCOVR	19	.098	-.210*	-.269**	.325**	.070	.054	1.450**	.517**	1.000					
INFLDENS	20	-.132	-.249**	-.321**	.325**	.275**	.232**	.500**	.052	.603**	1.000				
BRANDENS	21	-.023	-.275**	-.371**	.308**	.232**	.173*	.408**	.346**	.720**	.757**	1.000			
VIGOUR	22	.180*	-.103	-.140	.501**	.189*	.326**	.402**	.359**	.587**	.454**	.478**	1.000		
PRODUCTV	23	-.007	-.203*	-.293**	.398**	.181*	.109	.538**	.466**	.792**	.654**	.681**	.684**	1.000	
ADAPTBTY	24	.032	-.267**	-.297**	.407**	.215**	.153	.496**	.460**	.772**	.619**	.673**	.713**	.933**	1.000

Level of significance 5% : >0.164(*)

1% : >0.214(**)

characters. The four factors explained 71.6% of the total variance for morphological characters with the eigenvalues of 3.249, 2.421, 1.658 and 1.373 respectively. Three factors explained 84.97% of the total variance for agronomic characters with their respective eigenvalues of 2.897, 2.606 and 1.295. For the combined morphological-agronomic characters the four factors accounted for 72.09% of the total variance with the eigenvalues of 5.045, 1.932, 1.739 and 1.376 respectively. The sorted rotated factor loadings for morphological, agronomic and morphological-agronomic characters are respectively presented in Tables 5, 6 and 7.

In Tables 5, 6 and 7 the factor loading matrix has been rearranged so that the columns appear in decreasing order or variance explained by factors. The rows have been rearranged so that for each successive factor, loadings greater than .5000 appear first. Loadings less than .2500 have been replaced by zero.

The interpretations attached to these factors for the morphological characters are that the positive end of factor one is characterised by attributes responsible for the higher number of leaflets per leaf, obovate in shape, yellow flowers with few or no red marks and green bracts. Factor two represents characters associated with large bracts and corollas, the corollas being yellow in colour. The inflorescences are compact, having very many flowers and bracts. The third factor expresses thick and long internodes and long inflorescences. The fourth factor is associated with characters responsible for the flowers that are longer than the bracts.

For the agronomic characters the positive end of factor one is associated with characters responsible for bushy plants which are highly productive and adaptable while factor two indicates plants which are vigorous and leafy with high productivity. Factor three is associated with erect plants having very few leaves.

Table 5. Sorted rotated factor loadings for morphological characters in *Zornia* sp.

		Factor 1	Factor 2	Factor 3	Factor 4
NLEAFPLF	3	0.878	0.000	-0.[illegible]73	0.000
SHAPELL	5	0.864	0.000	0.000	0.000
SIZELL	7	0.858	0.000	0.000	0.000
BRACTISCO	12	-0.663	0.000	0.000	0.000
FLOWERCO	8	-0.643	-0.422	0.000	-0.325
BRACTSZE	17	0.000	0.878	0.000	0.000
FLOWERSZ	9	0.000	0.789	0.000	0.298
SPBRINFL	16	-0.297	0.782	0.000	0.000
ININDEL	13	0.000	0.000	0.769	0.000
ININDETH	14	0.000	0.261	0.740	0.000
FLOWERSZ	4	0.000	0.000	0.000	0.813
INFLLENG	15	0.000	0.000	0.564	-0.624
	VP	3.249	2.421	1.658	1.373

Table 6. Sorted rotated factor loadings for agronomic characters in *Zornia* sp.

		Factor 1	Factor 2	Factor 3
INFLDENS	20	.905	.000	.000
BRANDENS	21	.880	.295	.000
PLOTCOVR	19	.721	.532	.000
VIGOUR	22	.259	.837	.000
ADAPTBTY	24	.570	.751	.000
PRODUCTV	23	.600	.721	.000
PLGRFORM	10	.000	.000	.887
LEAFNESS	18	.000	.607	-.655
	VP	2.897	2.606	1.295

Table 7. Sorted rotated factor loadings for morphological-agronomic characters in *Zornia* sp.

		Factor 1	Factor 2	Factor 3	Factor 4
PRODUCTV	23	.910	.000	.000	.000
ADAPTBTY	24	.900	.000	.000	.000
PLOTCOVR	19	.869	.000	.000	.000
VIGOUR	22	.797	.000	.000	.000
BRANDENS	21	.733	.000	-.364	.000
INFLDENS	20	.632	.295	-.308	-.295
LEAFNESS	18	.613	-.567	.000	.000
FLOWERSZ	9	.538	.428	.000	.000
PLGRFORM	10	.000	.782	.000	.000
BRACTSCO	12	.000	.748	.000	.000
SIZEUL	7	.000	.000	.843	.000
SHAPELL	5	.000	.000	.817	.000
FLOWERSZ	4	.000	.000	.000	.892
BRACTSZE	17	.577	.000	.000	-.618
	VP	5.045	1.932	1.739	1.376

Considering the morphological-agronomic characters combined, the positive end of factor one has some resemblance to factor one for agronomic characters. It is characterised by high productivity, adaptability, plot cover, vigour, branching intensity, inflorescence density, leafiness and large flowers (corollas) and bracts. Factor two, on the other hand, is mainly characterised by plants having reddish or purple bracts, semi-erect to erect but scanty foliage and flowers of medium size. Factor three is associated with plants having obovate leaflets with low branching intensity and inflorescence density. Factor four is mainly characterised by flowers that are larger than the bracts.

The factor scores of individual accessions on the first four factors were plotted against one another under morphological, agronomic and all characters combined (Figures 1, 2 and 3). Clustering could be identified especially at the ends of the axes with most of the accessions scattered randomly at the point of origin.

Based on the morphological characters four clusters, (A, B, C and D in Figure 1) on the plot of factor 1 versus factor 2 were formed. Cluster A comprised *Zornia setosa* accessions, cluster B was composed of *Z. brasiliensis* while cluster C comprised accessions 11411 and 11424. These two accessions have not been identified, but they could possibly belong to *Z. lanata*. Cluster D was composed mainly of *Z. glabra*. Accessions belonging to *Z. diphylla* and *Z. pratensis* tended to form a continuum, which is not surprising since *Z. diphylla* is normally applied to a complex of species, both perennial and annual (Bogdan, 1977). This complex of species usually embraces such species as *Z. latifolia, Z. gracilis, Z. perforata, Z. pratensis* and several others.

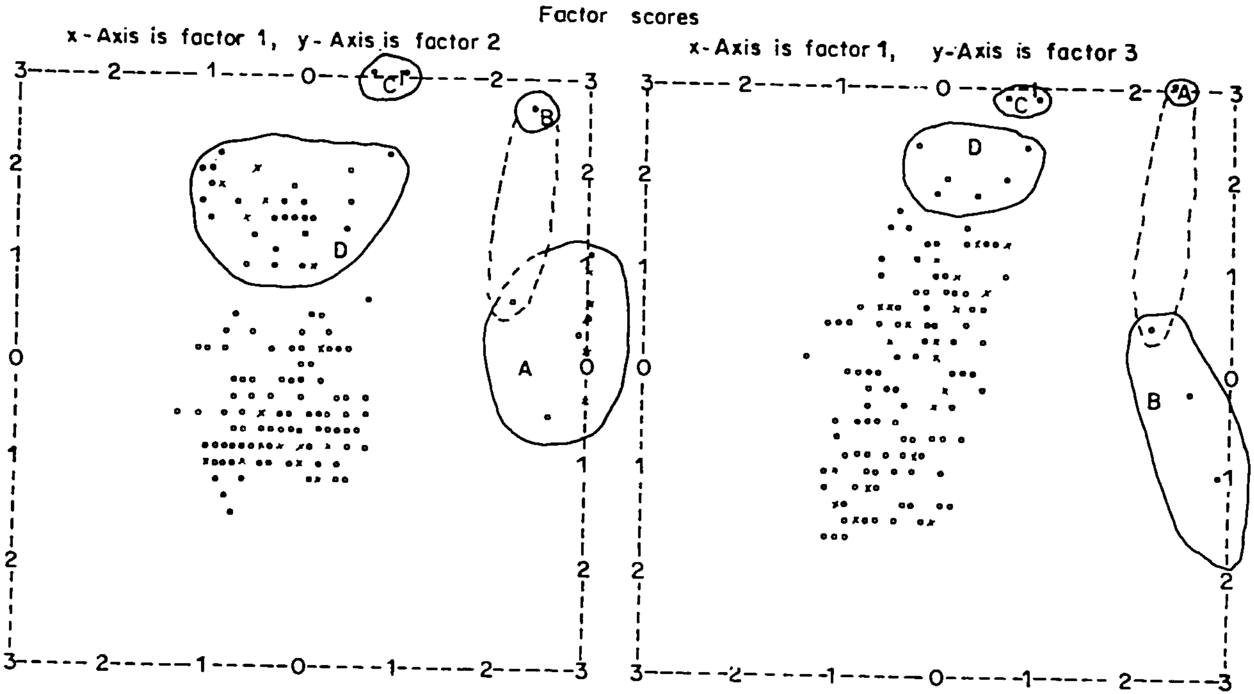
Groupings of accessions or clusters based on agronomic characters were almost similar to those based on the combined morphological-agronomic characters (Figures 2 and 3). Other species formed their own groups based on their stature and plant growth forms. Based on the clustering pattern of these accessions and the factor scores responsible for some characters, particular groups with particular characteristics can be picked out for further evaluation.

Cluster Analysis

As in the principal component analysis, the data were categorised into morphological, agronomic and morphological-agronomic characters. Using morphological characters, a minimum of ten clusters was formed with some non-conformist groups which later joined the rest of the clusters at higher amalgamation distances. The amalgamation distances ranged from 0.000 to 10.330 thus producing simple to complex fusions of accessions that produced a very large vertical tree dendrogram. Table 8 shows the composition of various clusters by accessions.

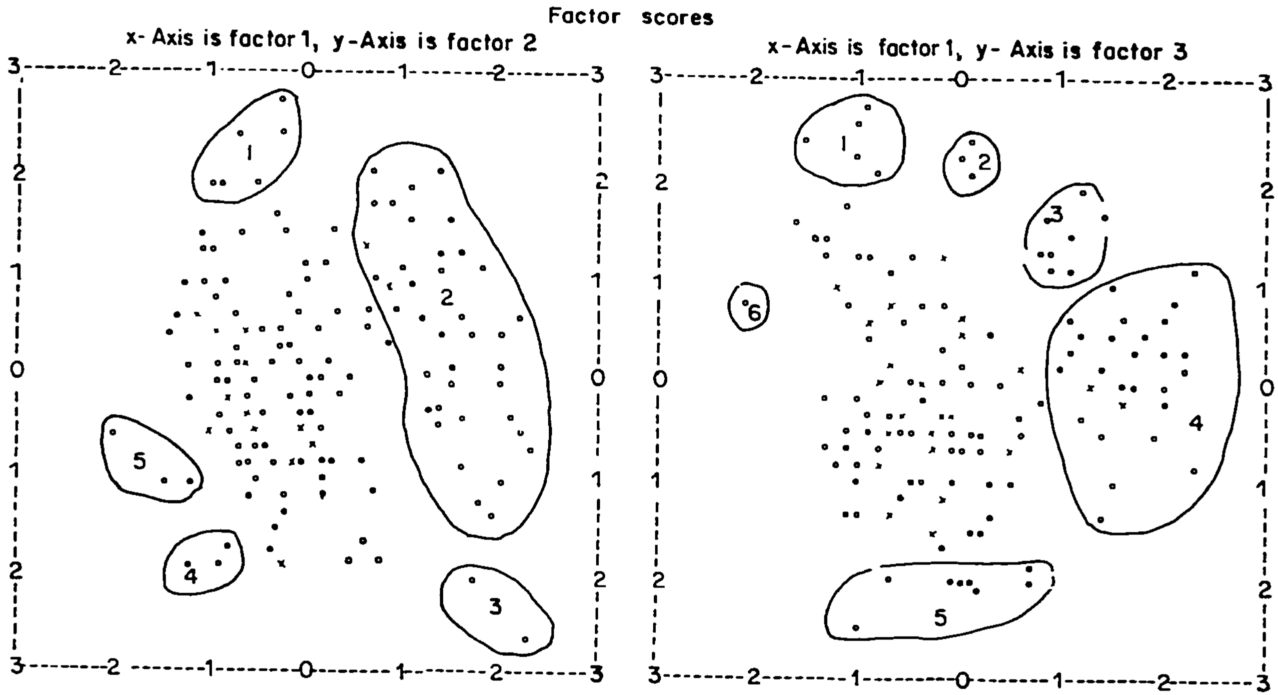
Some characteristic features of some clusters had a definitive role for particular species. Cluster 1, for example, was characterised by having four leaflets per leaf, obovate upper and lower leaflets, small yellow flowers with few or no red marks, very short and slender internodes and very short inflorescences and bracts. This cluster comprised all accessions of *Z. setosa* and one accession, ILCA 11476, of *Z. brasiliensis*. Cluster 2 had accessions whose flowers were shorter than the bracts. They had ovate to elliptic leaflets with a few accessions having lanceolate leaflets. They also tended to have medium to long inflorescences, medium to large spread of bracts or inflorescences and medium sized bracts. Accessions in this cluster belonged to *Z. glochidiata* and *Z. orbiculata*. Cluster 10, which was the largest, comprising 28 accessions, was characterised by medium to large flowers with inflorescences of medium length, leaflets that were more than twice as long as they were broad and medium-to-large spread of bracts on inflorescences

Figure 1. PCA morphological characters.



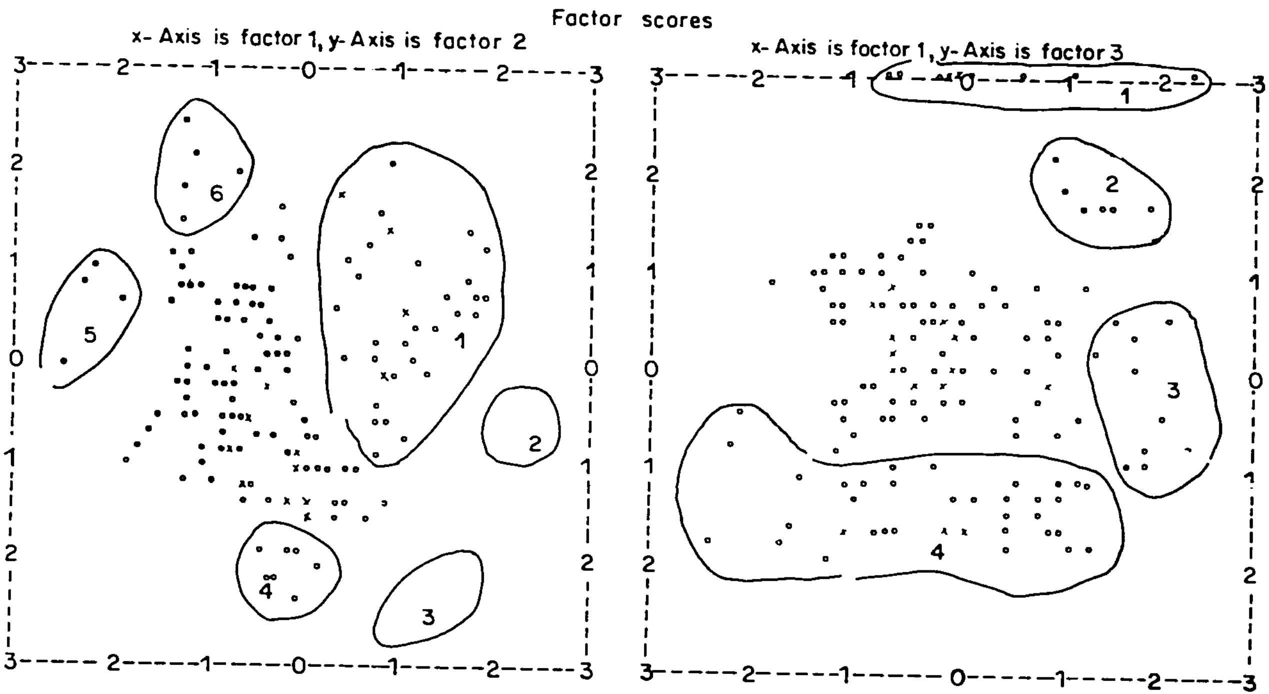
Scale is from -3 to +3. Factor scores greater than 3 are plotted as 3. Factor scores less than -3 are plotted as -3.

Figure 2. PCA agronomic characters.



Scale is from -3 to +3. Factor scores grea-er than 3 are plotted as 3. Factor scores less than -3 are plotted as -3.

Figure 3. PCA all characters.



Scale is from -3 to +3. Factor scores greater than 3 are plotted as 3. Factor scores less than -3 are plotted as -3.

Table 8. Accessions of Zornia species constituting various clusters in cluster analysis

Cluster	Morphological characters	All (combined) characters	Agronomic characters
1	13985, 9788, 10258, 10228 10303, 10538, 10259, 10320 9798, 10277, 9760, 11476	13985, 10259, 10277, 10538 9798, 10228, 10303, 9788 10258, 10320, 9760, 9158 11476	11517, 11349, 13839 11370, 11397
2	11428, 11374, 10312, 9789 10541, 10537, 9680, 9754 13839, 10319	11428, 11374, 10319, 13839 10312, 10541, 9789, 10537 9680, 9754	11354, 11432, 11410, 11366 11414, 11511, 11522, 11423 11418, 11403, 11402, 11396 11419, 11407, 11518, 11380 11416, 11439, 11363, 11485 11504, 11357
3	11426, 11358, 11416, 11419 11502, 11423	11517, 11484, 11388, 11392 11371, 11518, 11436, 11358 11416, 11405, 11511, 10234 11396, 11522, 11387, 11403 11402, 11344, 11418, 11477	9158, 11436, 11428, 10234 11345, 11409, 11515, 11430 11390, 11368, 10900, 11408 11514, 11394, 11427, 11477 10277, 10258, 9760, 9788 10320, 10902, 11351, 12429
4	11355, 11394, 11390, 11506 11432, 11438, 11362	11341, 11427, 11385, 11370 11352, 11508, 11480, 11417 11353, 11389, 10902, 11393 11348, 11363, 11397, 11339 11471, 11419, 11502, 11349 11357, 11390, 11394, 11430 11514, 11515, 11376, 11408 11520, 11391, 11338, 11504 11414, 11406, 11366, 11368	11341, 11385, 10538, 9798 11513, 9754, 9680, 11338 11376, 11406, 10228, 10303 11393, 11388, 11391, 11344 11389, 13984

Table 8. (Cont'd)

Cluster	Morphological characters	All (combined) characters	Agronomic characters
		11410, 11351, 11409, 11432 11354, 11485, 11481, 11380 11407, 11431, 11375, 11435 11340, 10900, 11513, 11439 12429	
5	11522, 11354, 11396, 11478 12429, 11477	11345, 11379, 13984, 11423 11464, 11478, 10613, 11342 12411, 11412, 11510, 11447 11372, 11438, 11461	11417, 11480, 11471, 11435 11348, 11340, 11353, 11508 11374, 11379, 11476, 11438 11353, 11502, 11375, 10259 11431, 11339, 11355
6	11349, 11434, 11353, 11368 11389, 11504, 12411, 11376 11520, 11408, 11417, 11414 11406, 11391, 11515, 11484 11348, 11400, 11430, 11339 11397, 11352, 11351, 11410 11409, 11471, 11464, 11514 11480	11466, 11507, 10901, 11367 13361, 11399, 11413, 11501 11386, 11415, 11519, 11524 11500, 11362, 11506	11426, 11387, 11358, 11405 11464, 11444, 11424
7	11513, 10900, 11435, 11375 11431, 11380, 11485, 11481 11407, 11439, 11418, 11405 11340, 11342	11364, 172, 11395, 11355 11434, 11445, 11460, 11505 11356, 11462, 11455, 11456 11458, 11448, 11452, 11643 11443, 11451, 11359, 11400 11450, 11459	11520, 11478, 11371, 11392 11437, 11484

Table 8. (Cont'd)

Cluster	Morphological characters	All (combined) characters	Agronomic characters
8	11412, 11370, 11385, 11393 10902, 11519, 11524, 11415 11371, 11500, 11427	11422 and 11437	10613, 12411, 11342, 11395 11364, 172, 11421
9	11518, 10901, 11501, 11413 11357, 11392, 11388, 11507 11466, 11367, 10613, 11386 13984	10234, 11426 and 11444	11347, 10312, 9789, 11501 10537, 11510, 11386
10	11372, 11510, 11356, 11462 11505, 11444, 11447, 11451 11643, 172, 11445, 11460 11395, 11443, 11448, 11456 11455, 11457, 11449, 11453 11458, 11450, 11454, 11452 11446, 11359, 11364, 11459	11347, 11424 and 11411	11459, 11359, 10541, 11447 11461, 11445, 11411, 11452 11456, 11458; 11505, 11466 10319, 11506, 11362, 11443 11450, 11400, 11367, 11519 10901, 11500, 11524, 11643 11399, 11454, 11415, 11451 11453, 11457, 11449, 11446 11448, 11462, 11434, 11507 11356, 11422
11	11422, 11347, 11437, 10234 11461, 11517, 11363, 11402 11344, 11379, 11345, 11387 11403, 13361, 11341, 11338 11399, 11424, 11411		

which were either purple in colour or had red marks. Cluster 10 was composed of *Z. glabra* and *Z. latifolia*. Other clusters tended to be an assortment of various species, namely *Z. diphylla, Z. latifolia, Z. pratensis* and other unidentified *Zornia* spp.

For clustering based on agronomic and morphological-agronomic characters, ten clusters could be identified in each case. However, based on agronomic characters the whole population could be divided into two major units. One group comprised accessions that ranged from creeping to decumbent and were of small stature (clusters 1 to 7). The second group was characterised by being decumbent to erect, of fair to very good leafiness, good to very good branching intensity, vigour, productivity and plot cover. The first group comprised such species as *Z. setosa, Z. glochidiata, Z. diphylla* and some unidentified species while the second group comprised mainly *Z. glabra* and *Z. latifolia*.

K-means Clustering

In the final K-means clustering analysis, divisions into 8, 10 and 12 clusters were specified under morphological, agronomic and morphological-agronomic characters (Appendix 1). This number was arrived at on the basis of the previous observation which indicated that during cluster analysis at least 10 clusters could be identified while in the principal component analysis a minimum of six clusters including the continuum of accessions scattered at the point of origin could be identified.

The characters or variables which were important in determining clusters were those with relatively high "F-ratios" of the between to the within cluster mean squares. The characters which had high "F-ratios" (>30) were adaptability, productivity, inflorescence density, branching intensity and plot cover. These characters determined clusters under agronomic characterisation while those under morphological characters were flower size, size of the lowest leaflets and shape of the leaflets of the lowest leaves. For morphological-agronomic characters were flower size, size of the lowest leaflets and shape of the leaflets of the lowest leaves. For morphological-agronomic characters the important variables responsible for clustering included the number of leaflets per leaf, flower (corolla) size, size of the lowest leaflets, productivity and adaptability.

Some clusters were either wholly or partially composed of accessions belonging to particular or closely related species. This was exemplified by the clusters under morphological characters. Cluster 1 is, for instance, composed of accessions belonging to *Z. brasiliensis* and *Z. setosa* only. *Z. brasiliensis* is represented in the ILCA collection by accessions 11347 and 11476 only. Cluster 2 is dominated by *Z. glabra* and *Z. latifolia* while cluster 3 is composed of the accessions 11411 and 11424 (possibly belonging to *Z. lanata*). Cluster 6 comprises accessions belonging to *Z. glochidiata* while cluster 7 has an assortment of species including *Z. diphylla, Z. pratensis* and *Z. glochidiata*.

DISCUSSION

Zornia is a genus of known notorious taxonomic difficulty. The significance of classifications of the species in this genus would possibly be in the application of various groupings to agronomic problems, particularly selection and/or breeding for specific purposes. The results of classification do not establish but merely suggest the potential of a given accession.

Plant evaluation is expensive in terms of time and effort, and it is known that certain species or genera are more likely to be of value than others. Selection of the materials to be used in the improvement of pasture germplasm depends on the available information about the germplasm. Coupled with the information on preliminary evaluation is the knowledge on characterisation of these materials both of which help in grouping the germplasm on the basis of morphological and agronomic characters.

Agronomic information is, of course, essential for an understanding of the range of variation available in the accessions as a guide to existing desirable combination of characters and to the beneficial recombinations that may be possible with genetic manipulation. A pure morphological or morphological-agronomic classification is liable to be insufficiently sensitive to agronomic heterogeneity. A pure agronomic classification is too crude to permit identification, owing to the limited numbers of attributes that can be devised for collection. There is ample evidence that classification provides the single most profitable technique for obtaining a preliminary synoptic view of a complex system (Williams *et al.*, 1973). In a study of this nature the groups of accessions may be regarded as centres of variation and allow the information to be presented in a more simple form than enumerating the properties of all individuals. So if a collection like this *Zornia* one is too large to permit succinct description, a classification in groups of known mean characteristics will still be necessary if the information is to be summarised and communicated to others.

Under morphological ordination and classification, accessions belonging to particular species or closely related species tended to form groups. *Zornia setosa* and *Z. brasiliensis* formed their own group; so did *Z. glabra* and *Z. latifolia* (with a few exceptions); and *Z. glochidiata*. A continuum of accessions belonging to *Z. diphylla, Z. pratensis,* some *Z. latifolia* and other unidentified *Zornia* spp. was formed. This was consistently so under the three types of analyses (PCA, CA and K-means clustering). Since morphological classification is basically very valuable for identification and description, such classification has provided a useful tool for that purpose. Whereas a mixed morphological-agronomic classification is useful for description, it also provides some guide to the agronomic potentiality of some of the groups. The groupings in this study tended to conform to this observation. Agronomic classification tended to differ from the other two. Here groupings were purely based on agronomic similarities. However, the clusters comprising some accessions of *Z. glabra* and *Z. latifolia* were similar in composition for the three categories of classification. Accessions of *Z. diphylla, Z. pratensis, Z. setosa* and *Z. glochidiata* tended to exhibit characteristics of poor agronomic potential while *Z. glabra* and *Z. latifolia* generally showed better agronomic potentiality. For example, in principal component analysis and cluster analysis accessions of *Z. glabra*, *Z. latifolia*, some *Z. glochidiata* and some unidentified *Zornia* spp. showed a high expressivity of branching intensity, inflorescence density, plot cover, productivity and adaptability. Good performance in a spaced-plant trial, however, does not guarantee good performance in a grazed pasture. Grazing of *Z. brasilensis* accessions, for example, had to be terminated at any point in time (CIAT, 1983-1985), at Guilichao, CIAT, although the preliminary evaluation of these materials had been promising.

However, because it is often uneconomic or even impracticable to carry out field trials of all available material, the function of methods such as those outlined in this paper is to select those accessions most likely to justify more intensive trials. Groupings of accessions and/or species have been obtained in this study and some of their characteristics spelt out. Choice of particular groupings will depend upon the use to which these materials are to be put. Groups comprising *Z. setosa*, *Z. glabra*, *Z. latifolia* and *Z. glochidiata* including their characteristics could give a guideline as to what use these selections could be put should they be advanced to further evaluation trials. The numerical methods of groupings are of particular value in the tropical genera which may require taxonomic revision like *Zornia*. Groupings defined on the basis of overall similarities of agronomic importance and morphology could well be of more value for practical purposes than stringently defined species and could be used equally well for communication purposes.

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Appendix 1. K-means of clustering for Zornia sp. Constitution by accessions of different clusters for various groups of clusters and categories of characters.

Cluster number	Morphological characters			Agronomic characters			All characters		
	Group 8	Group 10	Group 12	Group 8	Group 10	Group 12	Group 8	Group 10	Group 12
1	11347, 13985 9158, 10320 11476, 10538 10259, 10228 9798, 9788 9760, 10277 10258, 10303	11347, 13985 9158, 10320 11476, 10538 10259, 10228 9798, 9788 9760, 10277 10258, 10303	11347, 13985 9158, 10320 11476, 10538 10259, 10228 9798, 9788 9760, 10277 10258, 10303	11347, 11367 11500, 11450 11446, 11400 11449, 11451 11452, 11524 11453, 11448 10901, 11457 11458, 172 11519, 11356 11422, 11454 11643, 11415 11443	11347, 172	11347, 172	13985 9158, 10320 11476, 10538 10259, 10228 9798, 9788 9760, 10277 10258, 10303	13985 9158, 10320 11476, 10530 10259, 10228 9798, 9788 9760, 10277 10258, 10303	13985 9158, 10320 11476, 10538 10259, 10228 9798, 9788 9760, 10277 10258, 10303
2	11459, 11355 11462, 11356 11372, 11450 11443, 11359 11445, 11446 11447, 11449 11451, 11452 11364, 11460 11453, 11454 11643, 11448 11455, 11456 11395, 11457 11458, 172 11505, 11437 11444	11459, 11355 11462, 11356 11372, 11450 11443, 11359 11445, 11446 11447, 11449 11451, 11452 11364, 11460 11453, 11454 11643, 11448 11455, 11456 11395, 11457 11458, 172 11505, 11437 11444	11459, 11355 11462, 11356 11372, 11450 11443, 11359 11445, 11446 11447, 11449 11451, 11452 11364, 11460 11453, 11454 11643, 11448 11455, 11456 11395, 11457 11458, 172 11505, 11437 11444	10613, 11412 11342, 12411 11353, 11434 11364, 11395 11417	10613, 11412 11342, 12411 11353, 11434 11364, 11395 11417	10613, 11412 11342, 12411 11353, 11434 11364, 11395 11417	11459, 11355 11462, 11356 11372, 11450 11443, 11359 11445, 11446 11400, 11447 11449, 11451 11452, 11364 11453, 11454 11643, 11448 11455, 11395 11457, 11458 172, 11347 11460, 11456 11505, 11444	11459, 11355 11462, 11356 11372, 11450 11443, 11359 11445, 11446 11400, 11447 11449, 11451 11452, 11354 11453, 11454 11643, 11448 11455, 11395 11457, 11458 172, 11347 11460, 11456 11505, 11444	11356, 11347
3	11411, 11424	11411, 11424	11411, 11424	11461, 11518 11380, 11502 11396, 11445 11447, 11407 11416, 11418 11464, 11424 11439, 11363 11358, 11397 11444, 11419	11461, 11518 11380, 11502 11396, 11445 11447, 11407 11416, 11418 11464, 11424 11439, 11363 11358, 11397 11444, 11419	11461, 11518 11380, 11502 11396, 11445 11447, 11407 11416, 11418 11464, 11424 11439, 11363 11358, 11397 11444, 11419	11411, 11424	11411, 11424	11411, 11424

Cluster number	Morphological characters			Agronomic characters			All characters		
	Group 8	Group 10	Group 12	Group 8	Group 10	Group 12	Group 8	Group 10	Group 12
4	11426, 11484 11464, 11363 11432, 11339 11502, 11352 11410, 11351 11508, 11514 11409, 11419 11438, 11510 11397, 11471 11430, 11394 11423, 11511 11416	11426, 11484 11464, 11363 11432, 11339 11502, 11352 11410, 11351 11508, 11514 11409, 11419 11438, 11510 11397, 11471 11430, 11394 11423, 11511 11416	11426, 11484 11464, 11363 11502, 11419 11397, 11471 11423, 11462	11466, 11359 11459, 11372 10541, 11339 11476, 11355 11423, 11462 11506, 11411	11466, 11359 11459, 11372 10541, 11339 11476, 11355 11423, 11462 11506, 11411	11466, 11359 11459, 11372 10541, 11339 11476, 11355 11423, 11462 11506, 11411	11426, 11464 11363, 11339 11502, 11352 11410, 11351 11508, 11514 11409, 11419 11438, 11397 11471, 11416 11394, 11348	11426, 11464 11363, 11339 11419, 11397 11471, 11416 11423, 11437 11405, 11358 11432, 11430 11423, 11349	11426, 11464 11363, 11339 11419, 11397 11471, 11416 11423, 11437 11405, 11358
5	11341, 12429 11354, 11412 11342, 10902 11385, 11379 11380, 11513 11481, 11431 11485, 11345 11500, 11375 11436, 11439 11370, 11396 11506, 11427 11407, 11524 11415, 11393 10900, 11418 11477, 11522 11340, 11435 11519, 11405 11478, 11371 11517	11342, 11380 11513, 11439 10900, 11412 11405, 11517	11342, 11380 11513, 11439 10900, 11412 11405, 11517	10312, 11399 11460, 10319 11386, 13361 11455, 11456 11501, 11510 11413, 9789 10537, 11507 11505	10312, 11399 11460, 10319 11386, 11455 11456, 11501 11510, 11413 9789, 10537 11507, 11505	10312, 11399 11460, 10319 11386, 11455 11456, 11501 11510, 11413 9789, 10537 11507, 11505	11341, 12429 11354, 10902 11385, 11379 11380, 11513 11481, 11431 11485, 11345 11375, 11436 11439, 11370 11396, 11427 11407, 10900 11418, 11477 11522, 11340 11435, 11517	11341, 12429 11354, 10902 11385, 11379 11380, 11513 11481, 11431 11485, 11345 11375, 11436 11439, 11370 11396, 11427 11407, 10900 11418, 11477 11522, 11340 11435, 11517	11341, 12429 11354, 10902 11385, 11379 11380, 11513 11481, 11431 11485, 11345 11375, 11436 11439, 11370 11396, 11427 11407, 10900 11418, 11477 11522, 11340 11435, 11517

Cluster number	Morphological characters			Agronomic characters			All characters		
	Group 8	Group 10	Group 12	Group 8	Group 10	Group 12	Group 8	Group 10	Group 12
6	11428, 9754 10541, 10312 11374, 9680 9789, 10537 10319, 13839	11428, 9754 10541, 10312 11374, 9680 9789, 10537 10319, 13839	11428, 9754 10541, 10312 11374, 9680 9789, 10537 10319, 13839	11354, 11426 11481, 11432 11485, 11504 11410, 11402 11520, 11511 11414, 11366 15522, 11392 11437, 11405 11478, 11403 11371, 11387 11423, 11484 11338, 11391	11354, 11426 11481, 11432 11485, 11504 11410, 11402 11520, 11511 11414, 11366 15522, 11392 11437, 11405 11478, 11403 11371, 11387 11423, 11484 11338, 11391	11353, 11481 11432, 11485 11504, 11410 11402, 11511 11414, 11366 11522, 11405 11403, 11423 11387, 11426	11428, 9754 10541, 10312 11374, 9680 9789, 10537 10319, 13839	11428, 9754 10541, 10312 11374, 9680 9789, 10537 10319, 13839	11428, 9754 10541, 10312 11374, 9680 9789, 10537 10319, 13839
7	11461, 11357 11518, 11466 11367, 10234 11507, 11388 11399, 11408 13361, 10901 11417, 11392 11413, 11403 11422, 13984 11387, 11402 11386, 10613 11501, 11362 11480, 10234 11358, 11344	11422	11422	11349, 11428 11345, 11375 11352, 10259 11508, 11515 11409. 10234 13839, 11340 11348, 11517 11431, 11370 11480, 11435 11471, 11357 11379, 11427 11374, 11438	11349, 11428 11345, 11375 11352, 10259 11508, 11515 11409, 10234 13839, 11340 11348, 11517 11431, 11370 11480, 11435 11471, 11357 11379, 11374 11438	11349, 11428 11345, 11375 11352, 10259 11508, 11515 11409, 10234 13839, 11340 11348, 11517 11431, 11370 11480, 11435 11471, 11357 11379, 11374 11438	11461, 11466 12411, 11507 11417, 11353 11386, 10613 11412, 11434 11524, 13361 11367, 11399 11519, 11501 11500, 11342 11362, 11506 11415, 10901 11413, 11510 11422	11422	11422

Cluster number	Morphological characters			Agronomic characters			All characters		
	Group 8	Group 10	Group 12	Group 8	Group 10	Group 12	Group 8	Group 10	Group 12
8	11389, 11434 11390, 11400 11515, 11391 11348, 11366 11504, 11414 11353, 11406 12411, 11349 11368, 11520 11376, 11338	11389, 11434 11390, 11400 11515, 11391 11348, 11366 11504, 11414 11353, 11406 12411, 11349 11368, 11520 11376, 11338	11389, 11434 11390, 11400 11515, 11391 11348, 11366 11504, 11414 11353, 11406 12411, 11349 11368, 11520 11376, 11338	12429, 9754 11430, 9158 10902, 11385 11513, 11389 10320, 11344 10234, 11390 11436, 11394 11376, 10228 9798, 11351 11368, 11514 11388, 9788 9780, 9760 11406, 11408 10277, 10258 10303, 11393 10900, 11477 13984, 11341 13985, 10538	13985, 10538	13985, 10538	11389, 11344 11391, 11358 11338, 11520 11392, 11484 11371, 11376 11406, 11366 11402, 11414 11478, 11405 10234, 11504 11368, 11388 11408, 13984 11387, 11393 11403, 11357 11518	11344, 11391 11338, 11520 11392, 11484 11371, 11376 11406, 11366 11402, 11414 11478, 10234 11504, 11368 11388, 11408 13984, 11387 11393, 11403 11357, 11518	11344, 11391 11338, 11520 11392, 11484 11371, 11376 11406, 11366 11402, 11414 11478, 10234 11504, 11368 11388, 11408 13984, 11387 11393, 11403 11357, 11518
9		11357, 11518 11466, 11367 10234, 11507 11388, 11399 11408, 13361 10901, 11417 11392, 11413 11403, 13984 11387, 11402 11386, 10613 11501, 11362 11480, 10234 11358, 11344 11461	11357, 11518 11466, 11367 10234, 11507 11388, 11399 11408, 13361 10901, 11417 11392, 11413 11403, 13984 11387, 11402 11386, 10613 11501, 11362 11480, 10234 11358, 11344 11461		9754, 11430 9158, 10902 11385, 11513 11389, 10320 11344, 10234 11390, 11436 11394, 11376 10228, 9798 11351, 11368 11514, 11388 9788, 9680 9760, 11406 11408, 10277 10258, 10303 11427	9158, 11436 11477		11466, 12411 11507, 11417 11386, 10613 11412, 11434 11524, 13361 11367, 11399 11519, 11501 11509, 11342 11362, 11506 11415, 10901 11413, 11510 11461	12411, 11417 10613, 11412 11434, 11342 11353

Cluster number	Morphological characters			Agronomic characters			All characters		
	Group 8	Group 10	Group 12	Group 8	Group 10	Group 12	Group 8	Group 10	Group 12
10		12429, 11354 11412, 10902 11385, 11379 11481, 11431 11485, 11345 11500, 11375 11436, 11370 11396, 11506 11427, 11407 11524, 11415 11393, 11477 11522, 11340 11435, 11519 .1478, 11371 11341	12429, 11354 11431, 11485 11396, 11477 11522, 11340 11478, 11341		11367, 11500 11450, 11446 11400, 11449 11451, 11452 11524, 11453 11448, 10901 11457, 11458 11519, 11356 11422, 11454 11643, 11415 11443, 13361	11367, 11500 11450, 11446 11400, 11449 11451, 11452 11524, 11453 11448, 10901 11457, 11458 11519, 11356 11422, 11454 11643, 11415 11443, 13361		11339, 11352 11410, 11351 11508, 11514 11409, 11438 11394, 11432 11430, 11349 10234, 11511 11390, 11480 11515, 11348 11389, 11389	11339, 11352 11410, 11351 11508, 11514 11409, 11438 11394, 11432 11430, 11349 10234, 11511 11390, 11480 11515, 11348
11			11432, 11339 11432, 11339 11352, 11410 11351, 11508 11514, 11409 11438, 11510 11430, 11394 11511, 11390			11520, 11392 11520, 11392 11437, 11478 11371, 11338 11484			11355, 11462 11355, 11462 11372, 11450 11443, 11359 11445, 11446 11400, 11447 11449, 11451 11452 11364 1145[illegible] 11454 1164[illegible], 11448 114[illegible]5, 11395 1145[illegible], 11458 172, 11460 11456, 11505 11444, 11459
12			11412, 11385 11379, 11481 11345, 11500 11375, 11436 11370, 11506 11427, 11407 11524, 11415 11435			11430, 10902 11385, 11513 11389, 10320 11344, 10234 11390, 11394 11376, 10228 9798, 11351 11368, 11514			11507, 11386 11524, 13361 11367, 11395 11519, 11501 11500, 11362 11506, 11415 10901, 11413 11510, 11461

CHARACTERISATION AND EVALUATION OF FORAGE LEGUMES IN ETHIOPIA: PRELIMINARY EXAMINATION OF VARIATION BETWEEN ACCESSIONS OF *STYLOSANTHES FRUTICOSA* (RETZ.) ALSTON

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Abstract

A study was carried out on accessions undergoing agronomic evaluation and seed multiplication. A total of 93 accessions grown as spaced plants were involved and 18 simple morphological and agronomic data recorded. Principal component analysis, cluster analysis and K-means clustering were used on the data.

It was shown that although there existed a high level of agronomic heterogeneity and genetic variability among the accessions, more collections were inevitable to widen the genetic base of S. fruticosa *and cover areas particularly in Africa where this species is prevalent. It was also realised that a more systematic study of these accessions for fairly long periods might give a better understanding of these materials. Characteristics of various groupings are discussed.*

INTRODUCTION

The importance of a germplasm collection to those utilising it is very dependent on the availability of accurate descriptions of the accessions and on the taxonomic identification of the germplasm (Engels, 1986). Where there is a substantial number of accessions of one species or genus within the collection, efforts should be made to classify these into like groups. The objective of this classification is to allow the reduction of the number of accessions that have to be grown in the next phase.

The genus *Stylosanthes* comprises 30 to 40 species (Burt *et al.*, 1983; Stace and Edye, 1984), many of which are either agronomically unattractive or are of rare occurrence. By the beginning of 1984 the world collection of *Stylosanthes* spp. and *S. fruticosa* were as shown in Table 1. *Stylosanthes* species are adapted to quite different ecological situations and range from annuals to perennials. They also have different agronomic forms. This exemplifies the high range of variability within the genus.

S. fruticosa is regarded as an excellent forage legume in some parts of Africa. Its deep and strong tap root system makes it resistant to grazing. The prostrate forms have some value in protecting the soil against erosion. *S. fruticosa* is a species which has received less attention than its South American allies *S. guianensis* and *S. humilis*, particularly in Australia. It must be presumed to have considerable potential as a forage legume in regions with a single dry season. It is distributed in many countries in Africa as seen in Figure 1.

The latitude and longitude ranges within the current *S. fruticosa* collections were respectively between 12°00'N and 13°24'N and 02°19'E and 09°03'E for Niger, and for Ethiopia

Table 1. World collection of *Stylosanthes fruticosa* and *Stylosanthes* spp.

Institution[1/]	*S. fruticosa*	All *Stylosanthes* spp.
CIAT	10	2241
CSIRO	88	1451
EMBRAPA	0	1296
EPAMIG	1	626
University of Florida	23	838
ILCA*	164	858

[1/]CIAT = Centro International de Agricultura Tropical, Colombia.
CSIRO = Commonwealth Scientific and Industrial Research Organization, Australia.
EMBRAPA = Empresa Brasileira de Pesquisa Agropecuaria, Brazil.
EPAMIG = Empresa de Pesquisa Agropecuaria de Minas Gerais, Brazil.
ILCA = International Livestock Centre for Africa, Ethiopia.

*The figures for ILCA are as of 31/12/86, and these were not included in the original table.

Source: Stace and Edye (1984).

between 04°54'N and 07°11'N and 37°22'E and 39°30'E. Williams et al (1984), Lazier (1984), Skerman (1977), Thulin (1983) and IBPGR (1984) show that *S. fruticosa* is distributed in at least 23 African countries.

Despite this wide distribution of *S. fruticosa*, especially in Africa, the current collection at the International Livestock Centre for Africa (ILCA) is mainly from Ethiopia and Niger. Two accessions were acquired from the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia. In order to search for materials of agronomic potential, it is essential to collect sufficiently variable germplasm from many diverse environments and evaluate their forage potential.

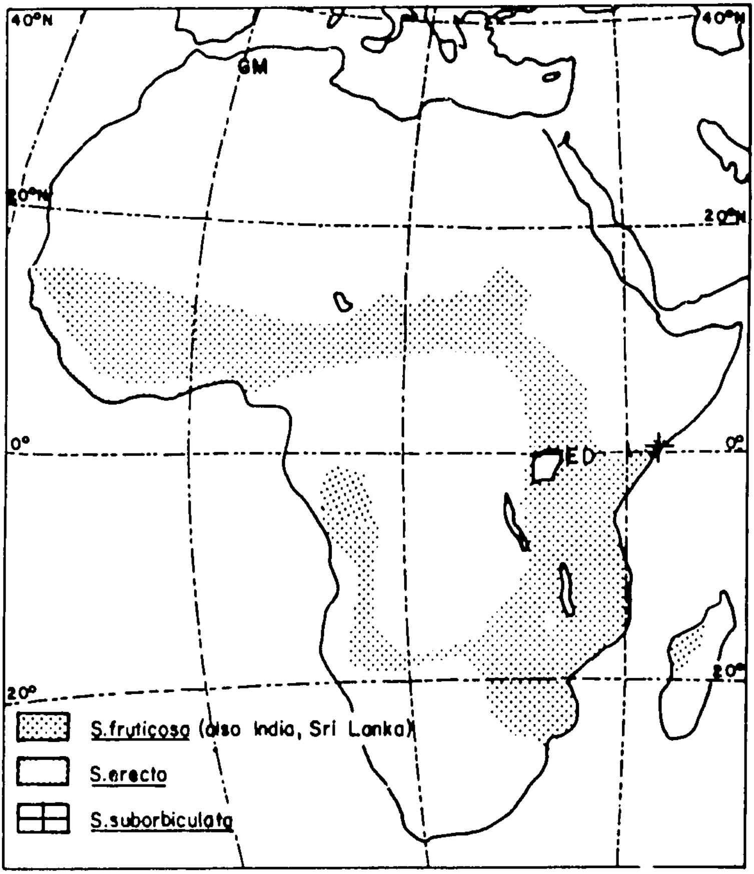
Some morphological and agronomic characters were studied for both identification purposes and assessment of agronomic value.

METHODOLOGY

Of the 164 accessions of *S. fruticosa* in the genebank at ILCA, 102 accessions were planted for agronomic evaluation and seed multiplication at Soddo in Sidamo, Ethiopia during April, 1985. The geographical and climatic description of Soddo and the planting procedure were as given in the *Zornia* paper in these proceedings.

These *S. fruticosa* accessions had been collected mainly from Ethiopia and Niger (Appendix 1). Those from Ethiopia were

Figure 1. Distribution of *Stylosanthes fruticosa* in Africa.



Source: Williams *et al.* (1984).

predominantly from Wolayta in Sidamo. In order to assess the existence of variations between the accessions that were undergoing agronomic evaluation, a study was superimposed on this trial. Observations were made when the plants were about 18 months old at the end of the rainy season. Eighteen characters (morphological and agronomic) on 93 accessions were selected based on the practical and field considerations at that particular time. These are given in Table 2 with their character state codes.

Principal component analysis and cluster analyses were done on the HP 3000 computer as described in the *Zornia* paper in these proceedings.

Table 2. **Morphological and agronomic characters taken at Soddo, Ethiopia, on *Stylosanthes fruticosa* and their character states.**

1. Plant growth form:
   1 = erect; 2 = semi-erect; 3 = ascendant;
   4 = ascendant/decumbent; 5 = decumbent,
   6 = decumbent/prostrate; 7 = prostrate
2. Plant height at centre of the plant excluding the central shoot (cm)
3. Plant height to highest point of central shoot (cm)
4. Canopy spread at the widest point (cm)
5. Canopy spread at the narrowest point (cm)
6. Mean number of branches originating from the main stem of all plants at or below 5 cm
7. Length of the longest primary branch (cm)
8. Average length of the spike (mm)
9. Adaptability:
   1 = negligible; 2 = very poor; 3 = poor;
   4 = fair; 5 = good; 6 = very good
10. Length of central leaflet of the leaf nearest to the spike (mm)
11. Width of the central leaflet of the leaf nearest to the spike (mm)
12. Central leaflet length/width ratio
13. Distance between base of centre leaflet to junction point of the two outer leaflets:
    1 = <1 mm; 2 = <2 mm; 3 = >2-<mm; 4 = >3-<4 mm;
    5 = >4-<5 mm
14. Stipule sheath length (mm)
15. Plot cover:
    1 = negligible; 2 = very poor; 3 = poor; 4 = fair;
    5 = good; 6 = very good
16. Height or distance of shoot tips from the ground level (mm)
17. Expressivity of the central (main) shoot:
    1 = negligible; 2 = very poor; 3 = poor;
    4 = fair; 5 = good; 6 = very good
18. Petiole length of the leaf nearest to the spike (mm)

RESULTS

Principal Component Analysis

The correlation matrix for the characters under study (Table 3) shows a number of high correlations. Plant growth form was most highly correlated with the height or distance of shoot tips from the ground but had otherwise low correlations with other characters. Other high correlations included canopy spread at the widest point with the length of the longest primary branch; canopy spread at the narrowest point and adaptability; and adaptability with plot cover. These correlations indicate that principal component analysis may provide a useful summary of the variability in the data.

When principal component analysis was applied to the data, four components or factors were found to have eigenvalues greater than unity. These four factors explained 71.6% of the total variance with 4.176% eigenvalues of 4.176, 2.606, 1.920 and 1.318 respectively. Based on the sorted rotated factor loading (Table 4) the following interpretations were attached to the factors.

The positive end of factor one is associated with the attributes responsible for characters of agronomic interest such as plants which are highly branched and quite bushy. Factor two represents characters associated with large leaflets while factor three expresses the high plant growth structure. The fourth factor is concerned with high leaflet length to width ratio.

The factor scores of the individual accessions on the first three factors were plotted against each other. Some clustering could be identified, although most of the accessions appeared to be scattered randomly about the origin. On the plot of factor 1 versus factor 2, for example (Figures 2 and 3), about six clusters could be identified.

Cluster 1 was composed of six accessions. These were characterised by long and wide central leaflet of the leaf nearest to the spike, petioles of the leaflet nearest to the spike being long and with distance between base of centre leaflet to junction point of the outer leaflets being between 1 and 2 mm.

Cluster 2 comprises ten accessions. These accessions have very good agronomic characters tending to those of *S. scabra* in growth form. They are quite bushy with a high branching pattern and very high adaptability and plot cover.

Cluster 3 is a uni-membered cluster composed of the accession 10539 whose central leaflet is very narrow and rather short. The accession, however, has similar agronomic features to those of the accessions in cluster 2, especially its wide canopy spread. This accession happens to be the one collected from the furthest east in the collection. It was collected from near Negele Borana in Sidamo, Ethiopia along the longitude of 39°30'E.

Cluster 4 is composed of ten accessions. Their main characteristic features are poor to fair adaptability and extremely poor to very poor plot cover. Exceptional cases are the accessions 13932, 13929 and 13973. However, 13973 has

Table 3. Correlation matrix for Stylosanthes fruticosa.

		PLGRFM 3	PLHTHT 5	CANSPW 6	CANSPN 7	NOBR 8	LPRBR 9	ADAPT 11	LFL 12	LFW 13	LFRAT 14	DIST 15	FLCOV 17	JTSJT 18
PLGRFM	3	1.000												
PLHTHT	5	-.227*	1.000											
CANSPW	6	.153	.193	1.000										
CANSPN	7	-.085	.314**	.795**	1.000									
NOBR	8	.154	.042	.482**	.500**	1.000								
LPRBR	9	.215*	.160	.933**	.799**	.421**	1.000							
ADAPT	11	.087	.384**	.612**	.663**	.421**	.585**	1.000						
LFL	12	-.159	.108	.022	.113	-.040	.116	.127	1.000					
LFW	13	-.201	.076	-.057	.031	-.146	.036	-.031	.678**	1.000				
LFRAT	14	.063	-.007	.080	.057	.141	.075	.147	.265*	-.508**	1.000			
DIST	15	-.233*	.149	.160	.148	.059	.156	.060	.36[illegible]**	.529**	-.244*	1.000		
PLCOV	17	.108	.314**	.539**	.555**	.319**	.534**	.798**	.169	.063	.077	.119	1.000	
HTSHT	18	-.630**	.379**	.111	.170	-.071	.061	.176	.052	.174	-.193	.210*	.089	1.000
LPETR	20	-.152	.121	.067	.227*	-.028	.074	.053	.401**	.454**	-.141	.549**	.111	.276**

LPETR = 20

LPETR 20 1.000

Level of significance: 5% : > 0.209(*), 1% : > -/271(**)

extremely poor plot cover. The rest of the accessions generally have few branches originating from the main stems at or below 5 cm.

Although this cluster exhibits a negative association of factors 1 and 2, there is no consistent pattern of expression of these characters for all the accessions in the cluster. These accessions, however, have a less than 1 mm distance between base of central leaflet to function point of the two outer leaflets. The central leaflets of the leaves nearest to the spikes are generally narrow and short, with a few exceptions being of medium length and fairly wide. These accessions other than those originating from Ethiopia have the longest spikes in the *S. fruticosa* collection at ILCA. The above mentioned features tend to separate accessions in cluster 4 from those of cluster 5.

Cluster 5 comprises nine accessions. These accessions have extremely poor to very poor plot cover and adaptability. They are of small stature and tend to form small bushes. Their leaflet and petiole characters are, however, almost similar to those of some accessions in clusters 1 and 2. It is interesting to note that although most of these accessions show poor adaptability, they were collected from Soddo, Sidamo in the neighbourhood of where they are currently being evaluated.

Cluster 6 is another uni-membered cluster comprising the accession 13924 from Niger. Like the other accessions appearing on the negative side of factor 1, it has very poor agronomic characters. It is also the only accession in the collection which was collected as far south in Niger as latitude 12°00'N.

Cluster Analysis

The 93 accessions of *S. fruticosa* in the final dendrogram were divided into ten clusters which distinctly are grouped into two main blocks comprising 15 and 77 accessions which will be referred to as groups A and B respectively. Group B comprising 77 accessions is solely composed of accessions collected from Ethiopia while group A comprises accessions from Ethiopia, Niger and CSIRO, Australia.

In group A the accessions which form the main cluster are 13942, 13850, 13860, 13893, 13890, 10829, 10523, 13919, 10431 and 10453. These are some of the accessions found with negative scores on factor 1 in the principal component analysis. These accessions are part of clusters 4 and 5 in the plot of PCA factor 1 versus factor 2 and are characterised by long spikes and short and narrow central leaflets of the leaf nearest to the spike. These accessions also have small bushes, very poor plot cover and adaptability.

Accessions in group B are characterised by large canopy spread, a fairly high number of branches originating from the main stem at or below 5 cm and good to very good adaptability.

Table 4. **Sorted rotated factor loadings for** *Stylosanthes fruticosa*.

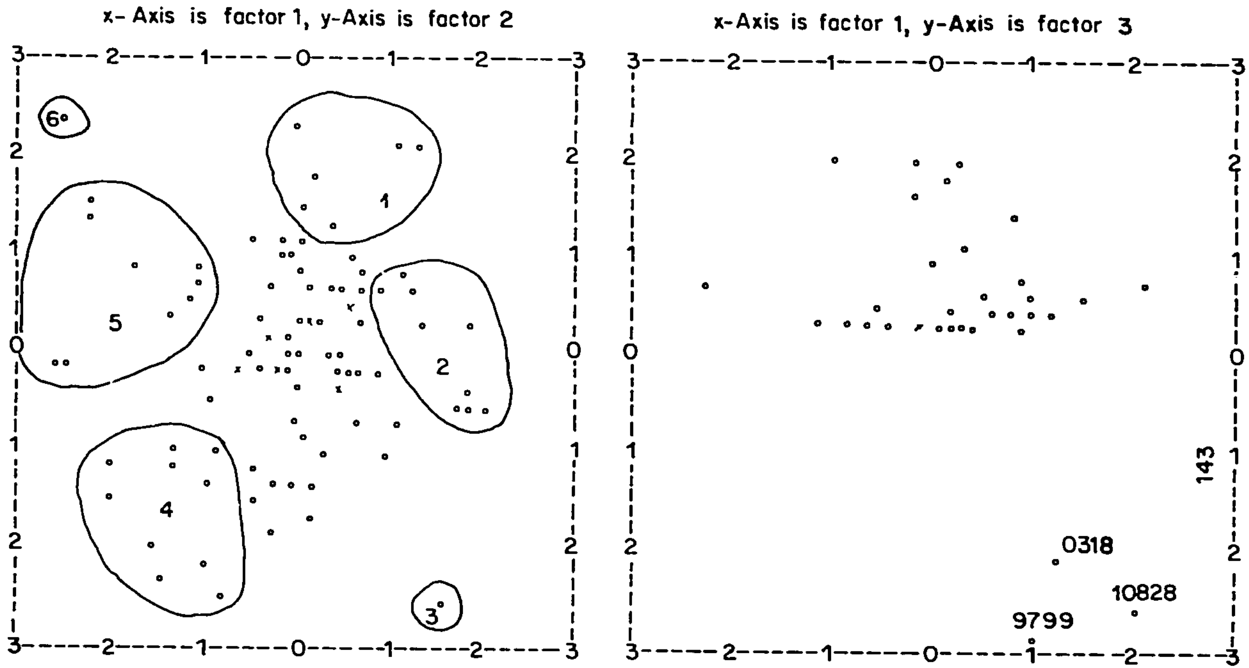
		FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
CANSPW	6	.907	.000	.000	.000
LPRBR	9	.890	.000	.000	.000
CANSPN	7	.882	.000	.000	.000
ADAPT	11	.813	.000	.000	.000
PLCOV	17	.740	.000	.000	.000
NOBR	8	.619	.000	.000	.000
LFW	13	.000	.890	.000	.000
LFL	12	.000	.767	.000	.565
DIST	15	.000	.739	.000	.000
LPETR	20	.000	.718	.000	.000
HTSHT	18	.000	.000	.858	.000
PLGRFM	3	.000	.000	-.790	.000
PLHTHT	5	.296	.000	.640	.000
LFRAT	14	.000	-.266	.000	.906
	VP	4.176	2.606	1.920	1.318

The above factor-loading matrix has been rearranged so that the columns appear in decreasing order or variance explained by factors. The rows have been rearranged so that for each successive factor, loadings greater than 0.5000 appear first. Loadings less than 0.2500 have been replaced by zero.

K-means Clustering

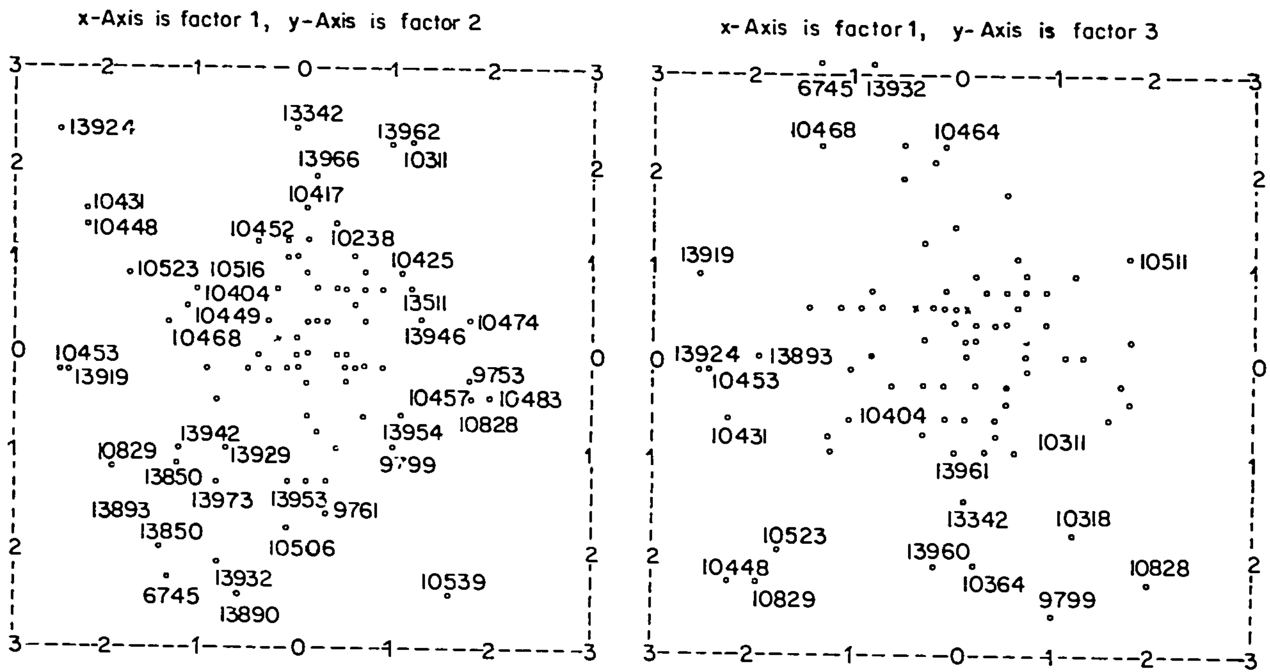
In the final K-means clustering analysis, divisions into 10 and 12 clusters were specified (Table 5). The relative importance of characters or variables in determining clusters can be judged by the "F-ratio" of the between to the within cluster mean squares. The most important variables were the average length of the spike, canopy spread at the narrowest point, the distance between base of centre leaflet to junction point of the two outer leaflets, canopy spread at the widest point, length of the longest primary branch, petiole length of the leaf nearest to the spike, plot cover and adaptability. The F-ratios for these variables were all above 10.0 with the highest being 28.0 for the average length of the spike. This can be illustrated by comparing clusters 2, 4 and 8. Cluster 2 is composed solely of accession 6745 which has the longest spike (of about 50 mm) among the collection; cluster 4 is also solely composed of 13342 which has the shortest spike (about 5 mm) and cluster 8 comprises accessions 13942, 13929, 13893, 13890, 13850 and 13860 whose spike lengths vary from 25 to 35 mm. The rest of the accessions had spike lengths ranging from 10 to 20 mm.

Figure 2. PCA for all characters Stylosanthes fruticosa.



Scale is from -3 to +3. Factor scores greater than 3 are plotted as 3. Factor scores less than -3 are plotted as -3.

Figure 3. PCA for all characters Stylosanthes fruticosa.



Scale is from -3 to +3. Factor scores greater than 3 are plotted as 3. Factor scores less than -3 are plotted as -3.

Table 5. Accessions constituting various clusters in the 10 and 12 group of K-meanc clustering.

Clusters	Group of 10 clusters	Group of 12 clusters
Cluster 1	*23 accessions* 10388, 10417, 10424, 1043/ 10433, 10432, 10493, 10511 10513, 13947, 13970, 10311 10322, 10396, 10420, 10482 10304, 10470, 10451, 13958 10391, 13971.	*10 accessions* 10428, 10493, 13947, 13970, 10396, 10482, 10391, 13959, 10304, 10470.
Cluster 2	*1 accession* 6745	*1 accession* 6745
Cluster 3	*5 accessions* 10445, 10440, 10514, 13932	*4 accessions* 10445, 10440, 13932, 10464
Cluster 4	*1 accession* 13342	*1 accession* 13342
Cluster 5	*18 accessions* 10501, 10506, 10515, 13949 13951, 13953, 13978, 13961 13954, 9761, 9796, 10364 10393, 10539, 9799, 10381 13973, 9678	*4 accessions* 9761, 10364, 10539, 9799
Cluster 6	*19 accessions* 10423, 10507, 13950, 13976 13975, 13972, 13968, 13966 13965, 13962, 13959, 9752 10280, 10288, 10415, 10452 10517, 10471, 13964	*17 accessions* 10507, 13950, 13976, 13975 13972, 13968, 13966, 13965 13962, 9752, 10280, 10288 10415, 10452, 10517, 10471 13964
Cluster 7	*8 accessions* 10449, 10448, 10431, 10523 13945, 13960, 10404, 10829	*8 accessions* 10449, 10448, 10431, 10523 13945, 13960, 10829
Cluster 8	*6 accessions* 13942, 13929, 13893, 13890 13850, 13860	*6 accessions* 13942, 13929, 13893, 13890 13850, 13860
Cluster 9	*5 accessions* 10468, 10453, 10516, 13924 13919	*5 accessions* 10468, 10453, 10516, 13924 13919
Cluster 10	*7 accessions* 10450, 10828, 10425, 10488 10474, 13946, 9753	*7 accessions* 10450, 10828, 10425, 10488 10474, 13946, 9753

Table 5 (cont'd).

Clusters	Group of 10 clusters	Group of 12 clusters
Cluster 11		*11 accessions* 10506, 10515, 13949, 13951 13953, 13961, 13954, 9796 10393, 10318, 13973, 9678 10501, 10514, 13978
Cluster 12		*15 accessions* 10417, 10424, 10437, 10433 10432, 10511, 10513, 10311 10322, 10420, 10451, 13958 13971, 10386, 10423

DISCUSSION

Cluster analysis, principal component analysis and K-means clustering were used to group similar accessions. The 93 accessions available for study were agronomically and morphologically diverse. With cluster analysis, some strong clusters were formed. However, about one-third of the accessions were non-conformist. Accessions collected from Niger tended to form a group of their own while the Ethiopian materials also tended to form theirs. There were exceptions to this, however. Group A in the cluster analysis which had all the Niger accessions, except 13929, had materials of Ethiopian origin too. However, a sub-cluster existed that comprised wholly of materials from Niger. This cluster was also consistent in both principal component analysis and K-means clustering. It was not possible to record some of the most important characters in *Stylosanthes* species such as flowering, seed and fruit characters in this study.

For proper characterisation and evaluation of plant genetic resources it is necessary to start from seeding to harvesting in order to obtain more meaningful inferences. Where time is limiting, however, a study such as is described here can give guidelines on what characters to use during evaluation and possible variations existing among the materials. All the analyses gave similar grouping of accessions. These groups were related to the geographical location or types of environments from which these plants were collected rather than variations between accessions from similar geographical location. For instance, the Niger material tended to be grouped together, while the Ethiopian material tended to form "agrotypes".

Since ILCA's collections of *S. fruticosa* is from such a limited part of its range, further collections from other African countries are highly recommended on the basis of the following observations:

1. There is need to collect and preserve genetic materials that are in danger of disappearing as a consequence of the destruction of natural vegetation.

2. There is need to increase the variability of collection from particular areas in relation to geographic, climatic and/or edaphic relevance.

3. There is need to collect genetic material in particular areas which in the past have been neglected or overlooked with regard to collecting activities.

Whereas it has been possible to obtain groups of accessions with particular characteristics based on the descriptions used in this study, the practical application of the findings has some limitations because of the omission of some important attributes. The variability existing within the species could therefore have been better described if more descriptors were used over a longer period of time. Despite the fact that little study has been done on *S. fruticosa* compared to the other *Stylosanthes* species, this characterisation and preliminary evaluation gives an indication of the variability or heterogeneity existing in *S. fruticosa* accessions currently available at ILCA.

ACKNOWLEDGEMENTS

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Appendix 1. Collections of Stylosanthes fruticosa being evaluated in Ethiopia.

	ILCA No.	Genus species	Country of origin	Original source or donor	Collecting institute	Other number	Remarks about origin or source
1	10388	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 47 N, 37 47 E
2	10391	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 51.5N, 37 43.5E
3	10404	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 46 E
4	10415	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 46 E
5	10417	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 46 E
6	10420	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 47 E
7	10423	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 47 E
8	10424	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 47 E
9	10425	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 47 E
10	10428	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 46 E
11	10482	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 50 N, 37 45 E
12	10474	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44.5N, 37 43.5E
13	10471	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44.5N, 37 43.5E
14	10470	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44.5N, 37 43.5E
15	10468	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44 N, 37 46.5E
16	10464	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44.5N, 37 42 E
17	10453	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 46 E
18	10452	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 46 E
19	10451	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44.5N, 37 43.5E
20	10450	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44.5N, 37 43.5N
21	10449	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 45.5N, 37 43.5E
22	10448	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 46 E
23	10445	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 46 E
24	10440	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 46 E
25	10437	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 47 E

Appendix 1. (cont'd)

	ILCA No.	Genus species	Country of origin	Original source or donor	Collecting institute	Other number	Remarks about origin or source
26	10433	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 47 E
27	10431	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 47 E
28	10514	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44 N, 37 46.5E
29	10488	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 50 N, 37 45 E
30	10493	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 45.5N, 37 43.5E
31	10502	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44 N, 37 43 E
32	10506	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44.5N, 37 42 E
33	10507	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44.5N
34	10511	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44.5N, 37 42 E
35	10513	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44 N, 37 46.5E
36	10515	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44 N, 37 46.5E
37	10516	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44 N, 37 46.5E
38	10517	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44 N, 37 46.5E
39	10523	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44 N, 37 43 E
40	13945	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 52 N, 37 58.5E
41	13946	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 53 N, 38 005E
42	13947	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 52 N, 37 31 E
43	13949	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 52 N, 37 31 E
44	13950	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 52 N, 37 31 E
45	13951	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 52 N, 37 31 E
46	13953	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 52 N, 37 31 E
47	6745	Stylosanthes fruticosa	Sudan	CSIRO	?	CPI 41219A	From Cunningham
48	13978	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 53.5N, 37 35.5E
49	13976	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 53.5N, 37 35.5E
50	13975	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 53.5N, 37 35.5E

Appendix 1. (cont'd)

	ILCA No.	Genus species	Country of origin	Original source or donor	Collecting institute	Other number	Remarks about origin or source
51	13973	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 53.5N, 37 35.5E
52	13972	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 53.5N, 37 35.5E
53	13971	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 52 N, 37 32 E
54	13970	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 52 N, 37 31 E
55	13968	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 51 N, 37 34.5E
56	13966	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 51 N, 37 31 E
57	13965	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 53.5N, 37 35.5E
58	13964	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 53.5N, 37 35.5E
59	13962	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 51 N, 37 31 E
60	13961	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 52 N, 37 31 E
61	13960	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 51 N, 37 31 E
62	13959	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 51 N, 37 31 E
63	13958	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 53.5N, 37 36.5E
64	13954	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 52 N, 37 44 E
65	9678	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	05 28 N, 38 16 E
66	9752	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	05 28 N, 38 16 E
67	9753	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	05 07 N, 38 17 E
68	9761	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	04 38 N, 38 14 E
69	9796	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	05 47 N, 39 17 E
70	9799	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	05 36 N, 39 21 E
71	10280	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 37 N, 37 34 E
72	10288	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 25 N, 37 22 E
73	10304	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 11 N, 37 36 E
74	10311	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44 N, 37 46 E
75	10318	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44 N, 37 48 E

Appendix 1. (cont'd)

	ILCA No.	Genus species	Country of origin	Original source or donor	Collecting institute	Other number	Remarks about origin or source
76	10322	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 48 N, 37 45 E
77	10364	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 07 N, 37 34 E
78	10393	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 44 N, 37 39 E
79	10396	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 42 N, 37 36 E
80	10539	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	05 26 N, 39 30 E
81	10828	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	05 43 N, 38 06 E
82	10829	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	04 54 N, 38 06 E
83	13942	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	12 21.2N, 02 22.2E
84	13932	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	13 24 N, 09 03 E
85	13924	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	12 00 N, 02 19 E
86	13919	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	12 09.6N, 02 23.4E
87	13893	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	12 17.8N, 20 33.1E
88	13890	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	12 16 N, 02 27.6E
89	13860	Stylosanthes fruticosa	Niger	ILCA/IBPGR	ILCA IBPGR	None	12 29.9N, 02 24.4E
90	13850	Stylosanthes fruticosa	Niger	ILCA/IBPGR	ILCA IBPGR	None	12 27.8N, 02 23 E
91	13342	Stylosanthes fruticosa	?	CSIRO	?	CPI 41116 A	From Cunningham Laboratory
92	10432	Stylosanthes fruticosa	Ethiopia	ILCA	ILCA	None	06 49 N, 37 47 E
93	13929	Stylosanthes fruticosa	Niger	ILCA/IBPGR	ILCA/IBPGR	None	12 24.4N, 02 22.6E

FODDER PRODUCTION POTENTIAL FOR ZERO-GRAZING SYSTEMS IN THE BIMODAL WEST USAMBARA MOUNTAINS OF TANZANIA

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Abstract

Overpopulation and increasing land pressure are resulting more and more in the deterioration of the agricultural potential in the hitherto highly productive agricultural areas of the West Usambara Mountains. To counteract this sad development, multiple measures have been applied. This paper presents the production potential data of fodders planted along contourlines and gives an outlook on environmental effects of such fodder lines in zero-grazed systems as part of an integrated approach to resolving the land pressure problems.

INTRODUCTION

The Western Usambara highlands are among the highly populated areas in Tanzania. Lundgren (1978) estimated the human population density at 180 people/km^2. Backeus (1982) predicted that by the year 1990 the population will have risen to 300 people/km^2. The high population has considerably increased pressure on land for agriculture. In certain areas people keep large herds of cattle which graze freely on the slopes as the communal grazing areas at the valley bottoms are used extensively for horticultural crops.

Free grazing has caused considerable surface runoff and soil erosion resulting in site deterioration with a consequent reduction in crop production. Lushoto district has tried to tackle the problem by implementing a major project on agroforestry throughout the Western Usambara highlands since 1980. The Soil Erosion Control Agroforestry Project (SECAP) applies an integrated extension approach which takes into account forestry, plant production and livestock measures using the macro-contourline approach. This approach integrates livestock production through "cutting and carrying" of fodder, zero-grazing and stall-feeding of livestock. It also integrates plant production through farmyard manure application due to stall-feeding operations, and it has a forestry component for fuel, construction and soil erosion control measures.

MATERIALS AND METHODS

In order to simulate the many site conditions in the West Usambara Mountains, four on-station trial fields covering various ecoclimatic conditions have been established since November 1985. Screening, elimination and management trials have been carried out using the randomised block designs. The macro-contourline is essentially an erosion control barrier consisting of four components, namely: a fodder bushline (preferably a legume), creeping legume line, fodder grass line and an agroforestry-tree line. This has been prepared and planted accordingly. The fodders are subjected to intensive cutting regimes. All the fodder components are cut half a year later after planting as this is what an average farmer would normally do. Thereafter the fodders are cut intermittently throughout the year once there is sufficient amount of regrowth on them.

Detailed ecological and meteorological measurements have been carried out in between the macro-contourlines. These have included:

Z: A zero treatment in which no soil control measure has been effected.

MI: Sunflower planted along the contourline.

T: *Grevillea robusta* line planted at 2m spacing along the countour.

GT: Guatemala grass with *Grevillea robusta* planted.

I: Maize planted as a sole crop.

II: Groundnuts planted as a sole crop.

III: Maize/groundnut mix stand planted.

IV: Maize/oil radish mix stand planted.

Erosion (-) and accumulation (+) of soil was measured in mm at soil erosion measuring stakes in between two contourlines.

RESULTS AND DISCUSSION

The data in the accompanying pages suggest that the macro-contourlines produced considerable amounts of biomass of both grass and legume species. In Table 1 for instance, the high productivity potential of the macro-contourlines has been demonstrated over sole stands. Th average dry-matter (DM) yields are nearly three times higher on macro-contourlines than on sole grasslands in Kenya. The macro-contourlines produced considerably more fodder in subsequent years than the first (Table 2). The grass yields were 22% whereas the yields of fodder bushes were 86% more in the second year. This was most probably due to better established root systems and more intensive cutting regimes after the first year.

Because of the diversity in topography and ecoclimatic conditions the most feasible fodder combinations for zero grazing systems in the West Usambara Mountains are presented in Table 3. The macro-contourlines appear to serve as basic fodder sources for zero grazing systems in the West Usambara Mountains. Due to stall-feeding of dairy cows with macro-contourline fodders, the milk yields in the West Usambara Mountains have increased already from 3 liters/day for local farmers to 7 liters/day for SECAP farmers.

Table 1. Fodder DM yields (t/ha) of various grasses.

	Sole grasses in Kenya		Macro-contourlines in Tanzania
Species/ location	Kisii	Kakamega	Lushoto
Banagrass	18.2	20.0	51.1
Guatemala grass	3.1	3.1	25.5

Table 2. Fodder DM yields (t/ha) of different fodder types.

Fodder type/ year	1st year	Mean of 2nd & 3rd year
Fodder grasses	2.10	3.30
Fodder bushes	1.75	3.25

Table 3. Feasible fodder combinations adapted to ecoclimatic zones/sites.

Site/ ecoclimatic	Fodder combinations
Mbwei in warm/dry	Bana grass *Desmodium intortum, Calliandra callothyrsus,* *Leucaena diversifolia, Neonotonia wightii,* *Stylosanthes guianensis.*
Uhiri and Silvici in humid/warm	Napier grass *Neonotonia wightii, Desmodium intortum,* *Desmodium uncinatum, Cajanus cajan,* *Leucaena leucocephala.*
Nywelo in dry/cold	*Tripsacum laxum, Desmodium intortum,* *Sesbania aculeata.*

The macro-contourlines also appear to have good environmental attributes based on detailed ecological and meteorological measurements carried out in cropped fields between macro-contourlines. As shown in Table 4, most of the soil was transported from treatments MI, T and GT; these were treatments that offered small erosion control because of poor ground cover. The zero treatment which was densely covered by natural fallow weeds had little soil movement.

Table 4. Soil loss as a result of macro-contourline plantings on a slope inclination of 21° between contourlines.

Decreasing soil movements -->							
MI		G	III	II	IV	I	Z
2.86(+)	2.44(+)	1.60(+)	1.42(+)	1.41(+)	1.17(+)	0.62(+)	0.26(-)

CONCLUSION

The contourline fodder production studies in the West Usambara Mountains have indicated potential for integrated approach to livestock production, crop production, soil erosion control and agroforestry. It has provided considerable amount of forage for zero-grazing systems by more than doubling the milk production capacity of the small-scale dairy farmers in the area. The contourline fodder and tree plantation also has helped to consolidate the erosion control role of these structures.

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THE CURRENT STATUS OF KNOWLEDGE ON THE FEED VALUE OF *CROTALARIA* SPECIES

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Abstract

The potential of Crotalaria ochroleuca *in farming systems in Tanzania is reviewed. Possibility of its use as a livestock feed is discussed in terms of its nutritive value in comparison to that of other legumes. However, there is no documented scientific information on its utilisation as a livestock feed in Tanzania. Factors that limit its wide utilisation as a feed are given. The paper suggests areas of research emphasising a multidisciplinary approach in attempting to appreciate the role of this wild legume in our agricultural systems.*

INTRODUCTION

The potential and use of forage legumes in farming systems and particularly in livestock nutrition has been well summarised by Tothill (1986). However research on indigenous wild legumes has been very limited compared to improved legumes. Tropical legumes which are used for forage have been cultivated during the last 50 years (Williams, 1983) yet the volume of unexplored genetic resource remains vast.

Crotalaria ochroleuca locally known as "marejea" in Tanzania is a well-known leguminous plant in the southern part of the country. As early as 1939, the legume was cultivated on small scale by Benedictine Fathers at Peramiho (Rupper, in press). It was mainly cultivated for the purpose of restoring fertility to the soil and to combat weeds. During shortages of fodder the legume was fed to dairy cows and calves. Although no quantified data is available, the performances of the animals were observed to be good.

The aim of this paper is therefore to highlight research work related with *Crotalaria* spp. in the field of animal production. Areas that need immediate investigations are emphasised.

BOTANICAL DESCRIPTION

Crotalaria, the genus to which *Crotalaria ochroleuca* belongs is the largest in tropical Africa and is commonly encountered in open places from mountains to semi-deserts, with over 500 species (Polhill, 1982). Most of the species are either annuals, semi-perennial, perennials, herbs or shrubs (Martin and Leonard, 1970). The leaves are either simple or compound with 3, 5 or 7 leaflets (Polhill, 1982).

Most of the species have numerous yellow flowers which later on bear tough-skinned seed pods that are inflated (Polhill, 1982). The number of seeds contained in a single pod depends on species but ranges from 5 to 50 seeds. The seeds are kidney-shaped, and their colour varies from olive-green to either yellow-red or brown.

CHEMICAL COMPOSITION

Dry-Matter Yield

Total dry matter is one of the factors which to a large extent determines the carrying capacity of a forage. In many selection programmes dry-matter yield is a key criteria for selection (Whiteman, 1980). Since *Crotalaria* spp. are among the high nitrogen fixers, this partly explains their yield potential because total dry matter and nitrogen fixation in legumes are known to be positively correlated.

In Upper Volta, it has been reported that *C. juncea* produced 10 tonnes/ha of dry matter without application of fertilizer (Anon, 1965). In Surinam when *C. quinquefolia* was grown for fodder, Ubels (1960) recorded an average of 17 tonnes/ha of dry matter. In the southern part of Tanzania, Mukurasi (1986) harvested 12 tonnes/ha of dry matter from *C. zanzibarica*. Comparatively, lucerne (*Medicago sativa*), which is one of the most important perennial fodders used in many regions of the world produces yields of 8-9 tonnes/ha (Whiteman, 1980).

Crude Protein, Minerals and Other Nutrients

Table 1 shows that an average crude protein content of *Crotalaria* spp. ranges from 10-35% with a mean of 24.1%. Crude protein content of the whole plant of *C. ochroleuca* is 28.1% and that of leaves is 34.5%. Although it is not possible to rank tropical legumes in terms of their protein content, according to Minson (1977) the mean crude protein of tropical legumes is 17.2%. The range may lie between 5.6% for *Stylosanthes humilis* to 35.8% for *Leucaena leucocephala*. It is therefore obvious that *Crotalaria ochroleuca* ranks high amongst other legumes in terms of crude protein content (Table 2).

The crude fibre content of a forage is another important measure of dry-matter intake and *in vivo* dry-matter digestibility. The efficiency of ruminant microbes during digestion is influenced to a large extent by lignin available in the fibre component. Van Soest (1965) showed that the proportion of potentially digestible components decline as the fibrous content increases. Thus the relatively fair crude fibre content in *Crotalaria* (Table 1) suggests a possible high intake and dry-matter digestibility.

Phosphorus and calcium content in *Crotalaria* spp. has been shown in Table 1. According to NRC (1978) the minimum level of phosphorus requirements for most animals is about 0.15%, which is below the amount available in *Crotalaria*. The calcium content is observed to be fairly high compared to the other legumes.

Table 1. Chemical composition of different Crotalaria species.

Species	Stage of growth	DM	CP	CF	EE	NFE	Ash	Sika	Ca	P	Remarks	Author
C. anagyroides	Vegetative		23.00	28.02	2.17	39.59	7.22	0.07	0.57	0.28		Dougal & Bogdan (1936)
C. falcata	Early fl.		34.81	21.07	2.33	33.83	7.36	0.09	0.94	0.36		Dougal & Bogdan (1936)
C. incana	Vegetative		23.79	27.06	2.87	36.43	9.85	0.11	0.81	0.26		Dougal & Bogdan (1936)
C. intermedia	Early fl.		28.85	22.08	3.31	35.86	9.90	0.37	0.72	0.33		Dougal & Bogdan (1936)
C. intermedia	Full fl.		21.41	35.72	1.93	34.03	6.91	0.07	0.44	0.27		Dougal & Bogdan (1936)
C. mucronata	"		31.65	21.37	2.89	55.85	8.24	0.06	0.75	0.35		Dougal & Bogdan (1936)
C. paulina	Vegetative		18.40	27.01	2.68	41.32	10.59	0.53	1.15	0.29		Dougal & Bogdan (1936)
C. petitiana	Early fl.		20.32	32.75	2.18	37.16	7.55	0.14	0.82	0.32		Dougal & Bogdan (1936)
C. relusa	Early fl.		21.50	20.40	2.47	46.34	9.28	0.39	1.22	0.26		Dougal & Bogdan (1936)
C. vallicola	Full fl.		25.97	26.29	2.18	37.91	7.65	0.28	0.57	0.28		Dougal & Bogdan (1936)
C. recta			20.27	8.10	4.3	41.1	-					Dougal & Bogdan (1936)
C. juncea	-	-	24.95	31.62	2.81	27.62	13.00	-	1.47	0.36		Balaraman and Vankaterkrishman (1974)
C. zanzibarica	Full fl.		35.00	14.00	-	-	-			0.23		Mukurasi (1986)
C. spectabilis		20.86	10.00	41.70	1.38	40.03	6.89					Neal and Becker (1933)
C. striata		25.92	17.00	39.14	2.04	37.90	3.89					Neal and Becker (1933)
C. intermedia		25.00	12.04	41.00	1.64	40.08	5.24	-	-	-		Neal and Becker (1933)
C. quinquefolia		20.00	-	-	-	-	-	-	-	-		Ubels (1960)
C. incana		24.32	14.40	46.40	1.27	35.12	5.81	-	-	-		Neal and Becker (1933)
C. ochroleuca	Early fl.	-	34.50	14.26	2.93	34.43	8.57	-	0.80	0.35	Leaves	Sarwatt (1986)
C. ochroleuca	-		28.10	38.10	-	-	8.10	-	-	-	Whole plant	Sarwatt (1936)
MEAN		23.22	23.67	28.22	2.43	37.33	8.00	10.21	10.86	10.30		

Table 2. Composition of nutritive value of different fodder legumes to Crotalaria (% DM basis).

Fodder	DM	CP	CF	EE	NFE	Ash	Ca	P	Author
Desmodium uncinata	-	23	8	-	-	-	-	-	Dougal & Bogdan (1936)
Desmodium uncinata	-	13	38.8	-	-	-	-	-	Milford (1967)
Stylosanthes humilis	-	14		-	-	-	-	-	Newman (1968)
Medicago sativa	-	21.2	29.4	1.4	35.1	9.1	-	-	Reddy (1969)
Leucaena leucocephala	-	25.9	12.4	-	-	11.0	2.36	0.23	
Leucaena leucocephala	-	20	21	6.4	49.26	11.2	2.2		Skerman (1977)
Crotalaria juncea	-	18.1	38.1	1.1	34.1	7.8	1.4	0.25	Reddy (1969)
C. ochroleuca	18.4	35.0	12.9	-	-	8.3	-	-	Sarwatt (1986)
C. ochroleuca	-		14.0	-	-	-	-	-	Mukurasi (1986)

UTILISATION AS FEED FOR LIVESTOCK

Research on the use of *Crotalaria* as a feed for livestock is very limited. The limited data that is available does not give quantitative investigations to establish the potential of *Crotalaria* spp. as a fodder plant. The only work that gives some detail is that of Balaraman and Vankaterkrishman (1974) who determined the nutritive value of *C. juncea* by conducting a metabolism trial using rams. The chemical composition and digestibility coefficients of sunnhemp hay used is shown in Table 3. Intake on average was 2.57 kg of dry matter per 100 kg body weight. The digestibility coefficients on consumption basis showed that the portion consumed was highly digestible. However, on feed basis the digestibility coefficients were very poor due to the fact that the rams chose the leafier parts of the plant and rejected the stems.

Table 3. Chemical composition and digestibility coefficients of *C. juncea* fed to sheep (% of DM).

Nutrients	Composition	Consumption basis	Feed basis
Dry matter	-	61.90	31.49
Organic matter	-	65.07	32.50
Crude protein	24.95	75.88	19.95
Crude fibre	31.65	59.53	53.68
Other extracts	2.81	35.62	24.39
NFE	27.62	57.30	27.51
Ash	13.00	-	-
Calcium	1.47	-	-
Phosphorus	0.36	-	-

Source: Balaraman and Vankaterkrishman (1974).

TOXICITY OF *CROTALARIA* SPP.

About 20 species of *Crotalaria* in tropical Africa alone are known to cause poisoning to cattle (Polhill, 1982). The symptoms seem to vary but common syndromes include inflammation of the horn, lameness and occasional starvation due to refusal by the animals to eat. The more lethal forms of poisoning affects the nervous systems, lungs and liver (Polhill, 1982). Poisoning seems to be serious at flowering and seed stages. Probably this is due to accumulation of the toxic alkaloid substance called *Crotaline* in these parts of the plant at maturity. Steyn and van de Walt (1945) reported loss of wool when sheep were fed *C. juncea* hay that was cut at flowering stage. They suggested that supplementation level in livestock feeds should not exceed 10% of the daily ration. Rupper (1984) observed that when *C. ochroleuca* seeds are sprinkled between the bags containing cereal grains, storage pests were killed instantly. They reappear six to nine months later. The fact that *Crotalaria* spp. have been observed to be toxic in one location but non-toxic in another, may explain the contradicting reports. The reasons why one species can be toxic in one location and non-toxic in another is still not yet understood. *Crotalaria ochroleuca* may be poisonous at flowering stage and the seeds may contain some poison, however, the legume seems to be non-toxic before flowering (Rupper, 1984). Further research on this area is needed to establish the effect of feeding the legume on livestock performance and health.

CONCLUSION

Crotalaria ochroleuca is regarded as a multi-purpose crop in agricultural production in Tanzania. Its importance as a livestock feed has been underscored because the plant is cultivated mainly in the area where a small number of livestock are kept and the land is not a limiting factor (Sarwatt, in press). In areas where cultivable land is a problem (e.g. in Arusha and Kilimanjaro regions) the legumes can be intercropped with regular food or cash crops.

The legume will provide nitrogen to the crops intercropped with and assist in the control of weeds and nematodes. The green part can be cut two to three times and fed to livestock. Every time the legume is cut, the nodules senescent thus releasing more nitrogen and other nutrients which can be utilised by the accompanying crops.

Research on the multi-purpose use of "marejea" is very limited in Tanzania. Most of the information available is mainly from the farmers' experience, which fails to answer questions like "how much N is fixed by marejea under the present farming system," or "how much marejea should be fed to a dairy cow for efficient milk production". For these questions to be answered, a multi-disciplinary approach is needed. Lack of scientific information on its feed value as regards feed intake, digestibility coefficients and safe levels of supplementation calls for an urgent need to assess the animal production potential of this plant as a cheap fodder legume.

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A REVIEW OF PASTURE AND FODDER CROPS GERMPLASM EVALUATION AT UYOLE, MBEYA IN TANZANIA

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Abstract

Since 1970 different pasture grasses, perennial legumes and annual fodders have been introduced and evaluated at Uyole. Initial introductions were temperate species among which only Trifolium repens *proved adapted to the Kitulo plateau where they are presently grown on a large scale. Further evaluations involved both tropical and subtropical species with Rhodes grass (*Chloris gayana *Kunth) as a locally adapted reference species. At Uyole several introduced species have outyielded Rhodes grass and future work will look at the chemical composition of these species at different growth stages. Among the legumes,* Desmodium *spp. cv Greenleaf and Silverleaf have shown good adaptation at Uyole and a few of the substations. These species have mixed well with most grasses.* Neonotonia wightii *cv Tinaroo and* Macroptilium atropurpureum *have also shown good promise at Uyole.*

*Amongst the perennial fodders, Napier grass (*Pennisetum purpureum *Schumach) has shown a wide adaptation to different localities and is currently used by most small-scale dairy farmers for fodder.*

Lupinus *spp. among the annual fodders has grown and stood well into the dry season at Uyole when planted late in the growing season. Oats cultivars have not been successful due to poor crown rust resistance. Current evaluations have included* Triticale *cultivars which have outyielded oats. Fodder beets have been evaluated but have failed to bolt.*

Animal production evaluations at Uyole have just been initiated and preliminary results have indicated that a grazing pressure of as high as 32 cows/ha can be achieved on some of the forages and fodders without affecting milk production drastically.

INTRODUCTION

The Southern Highlands of Tanzania cover vast areas of natural grasslands with varying land topography where the overstorey comprises Miombo woodland. On the hillsides and on undisturbed flatlands *Hyparrhenia* and *Themeda* spp. form a dense cover. These grasslands often lack local legumes, and therefore increased animal production (beef or milk) cannot be expected. The increasing population pressure especially in Mbozi, Rungwe and Mbeya districts have forced farmers to develop a forage-feeding system where very small areas could be grown with improved pastures.

Due to the low yield and quality of natural pastures a search into better quality grasses was initiated in 1970 at Uyole to cater for the four regions of Iringa, Mbeya, Rukwa and Ruvuma.

The work reported is mostly from Uyole, and it is only recently that germplasm evaluation has been started in Iringa and Rukwa Regions.

This paper broadly covers germplasm evaluations carried out at Uyole (Long. 33^{o} 32'E; Lat. 8^{o} 55'W) at an altitude of 1800 m with an average rainfall of 870 mm. Mean maximum temperatures range from 21-27^{o}C and mean minimum temperatures of 8-14^{o}C (Heady, 1978). The soils developed from volcanic parent material and contain pumice. They have recently been classified as Eutrandepts (Soil survey USDA classification) (Kamasho and Singh, 1982). They have a medium to slightly acid reaction (pH 6.5) and have a light texture (clay-loam). Phosphorus levels hardly reach 5 ppm. Copper is deficient in such soils.

PASTURE PLANT EVALUATION

Grasses

Initial grass introduction started in 1970 at Uyole from Sweden. They were mainly temperate grasses. A list of first introductions is shown in Table 1. In two seasons most temperate grasses proved a failure at Uyole despite a high nitrogen application rate of 120 kg N/ha. Only perennial and annual ryegrasses were worth harvesting. However these did not survive the dry season and due to poor seed set they had to be abandoned. However, *Lolium* spp. have proved a success on Kitulo plateau (2900 m.a.s.l.), and the species is now grown on a large scale for dairy production.

During the same season Rhodes grass and Nandi setaria were introduced from Kitale and compared at Uyole under different nitrogen levels. Further comparisons with Congo signal, Italian ryegrass and perennial ryegrass showed the latter to be low-yielding in terms of dry matter as indicated by Table 2. Among all grasses Nandi setaria showed a much higher nitrogen efficiency followed by Rhodes grass. The two temperate species showed both low yields and low nitrogen efficiency. After the second season the temperate species were attacked by cutworms and had to be dropped out. Their seeding qualities were also poor.

No chemical analysis was made on the different grass species due to lack of analytical facilities at the centre. Further evaluations had then to be based on Rhodes grass and Nandi setaria for their proved high yield with a good nitrogen response. Further comparisons were made involving molasses grass and coloured guinea grass (Anon, 1976). Both coloured guinea and molasses grass gave 5-6 t DM/ha in three cuts at 40 kg N/ha fertilizer rate compared with 6 t/ha for Rhodes grass.

During 1974 further introductions were made from Kitale, Kenya where Pokot Rhodes, Mbarara Rhodes, Masaba Rhodes and Molasses grass were compared with the locally growing Rhodes (Mbeya ecotype). All Rhodes cultivars did not yield significantly higher than Mbeya ecotype at all nitrogen levels (0-350 kg N/ha) while the rest of the grasses actually gave lower

Table 1. A list of grass species introduction at Uyole in 1970.

Species	Cultivars	DM yield kg/ha 1970/71	1971/72
Phleum pratense			
(Timothy)	Vallo	-	-
	Kaumpe II	-	-
	Omria	-	-
	Engmo	-	-
	Bottnia II	-	-
	Vanadis	-	-
Festuca pratensis			
(Meadow fescue)	Mimer	-	-
	Sena	-	-
	Bottnia II	-	-
	Loeken	-	-
Dactylis glomerata			
(Cocksfoot)	Frode	-	-
	Tardus II	-	-
Poa pratensis			
(Bluegrass)	Flyking	-	-
Lolium perenne			
(Perennial ryegrass)	Delta	3490	-
	Viva	2720	-
	Viris	3240	-
Lolium multiflorum			
(Annual ryegrass)	Imperial	6580	1770
	Novita	5000	1400
	Barwoltra	5700	-
	Barmultra	5270	-
	Tawera	5540	1500
	Tetrone	5410	-
	S.V. 02050	-	1810
	H.G. 7222	-	1470

yields. During 1975/76 season a chemical analysis based on % crude protein and *in vitro* dry-matter digestibility were carried out on Pokot Rhodes, Nandi setaria and Mbeya ecotype Rhodes as shown in Table 3 for three boot-stage cuts.

On the whole, Nandi setaria contained more crude protein at most nitrogen levels. Variation among cuts was not expected since the cutting interval and growth stage was the same for all cuts. INVODMD seemed not to be affected by the nitrogen level. Quality changes were not pronounced up to 150 kg N/ha implying higher N dressing requirements on the low N status soils of Uyole. Pokot Rhodes gave lower protein content than Mbeya Rhodes which also displayed lower INVODMD. To date, seed increase and distribution is based on Mbeya Rhodes because of its superiority over the introduced cultivars from Kenya.

Table 2. Dry-matter yield (t/ha) of different grass species under nitrogen application at Uyole (mean of three years).

Nitrogen	Rhodes grass		Nandi Setaria		Congo signal		Italian ryegrass		Perennial ryegrass	
Kg/ha/yr	Kg DM/ha	Kg DM/KgN	Kg DM/ha	Kg DM/KgN	Kg DM/ha	Kg DM/KgN	Kg DM/ha	Kg DM/KgN	Kg DM/ha	Kg DM/KgN
0	3700		2370		1000		660		640	
60	6020	39	5000	44	-	-	-	-	-	-
120	8720	42	7820	45	3830	24	2750	17	2930	19
240	14120	43	14820	52	6860	24	4760	17	3390	11
360	1786	39	18160	44	-	-	-	-	-	-
480	21030	37	21460	40	9990	19	8040	15	7900	15

Source: Anon (1976).

Table 3. Crude protein (% of DM) and dry-matter digestibility of three grasses under nitrogen application (Trial 116/74).

Nitrogen KgN/ha/ cut	Grass species	1st cut (Jan. 1976) CP (%)	1st cut (Jan. 1976) INVODMD (%)	2nd cut (March 1976) CP (%)	2nd cut (March 1976) INVODMD (%)	3rd cut (May 1976) CP (%)	3rd cut (May 1976) INVODMD (%)
0	Mbeya Rhodes	9.2	57.5	-	63.3	10.6	52.9
	Pokot Rhodes	9.6	57.7	-	75.0	9.2	58.0
	Nandi Setaria	9.3	66.3	-	70.4	10.6	64.6
50	Mbeya Rhodes	8.1	59.4	8.0	54.6	7.9	63.5
	Pokot Rhodes	7.2	60.1	7.8	59.1	[illegible].8	59.1
	Nandi Setaria	8.6	64.8	8.1	65.6	8.3	66.2
100	Mbeya Rhodes	9.4	63.3	14.2	59.3	8.0	55.8
	Pokot Rhodes	8.7	65.4	8.2	59.5	6.5	66.3
	Nandi Setaria	10.3	60.4	9.6	55.8	9.0	64.4
150	Mbeya Rhodes	11.0	63.8	13.0	53.5	15.5	53.2
	Pokot Rhodes	11.9	67.2	10.9	66.1	9.1	60.0
	Nandi Setaria	14.2	61.4	12.6	57.0	11.4	67.3
200	Mbeya Rhodes	15.7	60.0	10.5	63.2	12.1	58.9
	Pokot Rhodes	15.5	63.9	14.6	68.4	9.6	66.1
	Nandi Setaria	16.6	61.4	17.3	71.8	11.9	65.1
250	Mbeya Rhodes	17.5	64.7	18.3	69.4	13.1	57.8
	Pokot Rhodes	15.4	62.2	16.2	61.5	12.2	68.8
	Nandi Setaria	19.2	60.2	16.8	60.5	15.2	67.6
300	Mbeya Rhodes	17.0	62.0	16.9	60.4	11.3	55.8
	Pokot Rhodes	16.1	59.7	15.1			64.2
	Nandi Setaria	18.7	64.1	16.5	64.2	15.8	71.1
350	Mbeya Rhodes	17.6	61.1	17.7	59.2	12.1	53.2
	Pokot Rhodes	16.7	63.5	17.4	60.5	12.9	68.9
	Nandi Setaria	19.9	61.3	18.3	63.2	15.5	67.9

Legumes

Due to the increasing number of small-scale dairy farmers in the Southern Highlands, the reliance on fertilizer nitrogen was considered not possible as in most cases the capital available is not enough even for the food crops. The highlands' natural pastures lack local legumes and most of them had to be introduced. Introduced legumes include Greenleaf Desmodium, Silverleaf Desmodium, Siratro, Centro, Puero, Calopo, Clitoria, Neonotonia, Kenya white clover, Subterranean clover, Cook stylo, Hamata stylo, Seca stylo, Red clover, Lablab and Vicia or common vetch. Initial legume evaluations started in 1972. Most legumes did not germinate (Trial 105/72) except Greenleaf and Silverleaf Desmodium. Most of these were again introduced from Australia in 1981 as will be discussed under mixtures. Both cultivars of Desmodium have proved well suited to Uyole (1800 m.a.s.l.) Mbimba (1525 m.a.s.l.), Rungwe district (Mbeya) and Njombe district (Iringa). Further evaluations are now being carried out at

Mitalula (1055 m.a.s.l.) Nkundi (1975 m.a.s.l.) and Ismani (1370 m.a.s.l.). Seed increase is now being carried out for the two cultivars for further evaluation in different localities and distribution to areas where the legume has already been tested.

Mixtures

During 1971/72 season all the above legumes were grown in mixture with either Rhodes grass or Nandi Setaria. Most legumes did not germinate and those that germinated did not form an adequate ground cover, and some did not tolerate the dry season. Further mixture evaluations were made in 1979-1986 season (Trial 505-79) and results are shown in Table 4.

Table 4. Dry-matter yields (kg/ha) of mixtures and their components in pure stands (yield aggregates for three cuts/annum).

Year	Mean pure grass yield	Rhodes/ Greenleaf Desmodium mixture	Rhodes Silverleaf Desmodium mixture	Greenleaf	Silverleaf
1980	11670	15580	14230	13810	11810
1981	3095	5980	5290	6760	5150
1982	4935	5330	4190	5870	4290
1983	8700	7250	6580	7340	7650
1984	4210	4130	4740	3920	5280
1985	3665	3650	3870	4100	4040
1986	6115	5420	5370	5510	5300
Means	6055	6760	6320	6760	6220
Standard deviation	±3100	±4063	±3597	±3355	±2728

The overall mixture effects were masked especially after the second year for the two legume cultivars, and this was worsened after the fifth year due to ingress *Hyparrhenia* sp. During the first year a chemical analysis was made on all the three cuts as shown in Table 5. Only crude protein was determined due to lack of facilities for other analyses.

Irrespective of cut number, there was an increase in the crude protein content when Desmodium was included. Pure legumes, however gave higher values than the mixture.

Table 5. Crude protein content (% dry-matter bases) of pure Rhodes, Rhodes/Desmodium and pure Desmodium at Uyole.

Cut No.	Pure Thodes	Rhodes/ Greenleaf Desmodium	Greenleaf Desmodium	Pure Rhodes	Rhodes/ Silverleaf Desmodium	Silver-leaf
1st cut 9/1/80	11.3	13.7	19.2	10.8	13.2	18.0
2nd cut 17/3/80	8.8	13.3	13.9	8.5	13.5	19.2
3rd cut 18/6/80	7.0	10.2	13.7	5.9	10.2	9.0

During the 1981/82 growing season different grass and legumes species and cultivars were introduced from Australia. Among the grasses we had:

Cenchrus ciliaris cv Biloela
Panicum maximum var. *typica* (common Guinea) cv Riversdale.
Panicum maximum cv Gatton
Panicum maximum cv Hamil
Setaria anceps cv Narok
Setaria anceps cv Nandi
Setaria anceps cv Kazungula
Brachiaria decumbens (Signal grass) cv Basilisk.
Paspalum plicatulum (Plicatulum) cv Rodd's Bay
Paspalum plicatulum (Plicatulum) cv Bryan
Urochloa mosambicensis (Sabi grass) cv Nixon.

The legumes included:

Centrosema pubescens cv Common Centro
Neonotonia wightii cv Tinarro
Macroptilium atropurpureum cv Siratro
Medicago sativa (Lucerne) cv Hunter River
Stylosanthes guianensis cv Cook

Stylosanthes hamata (Caribbean stylo) cv Verano
Stylosanthes scabra (Shrubby stylo) cv Seca
Trifolium semipilosum (Kenya white clover) cv Safari
Trifolium repens (white clover) cv Haifa.

The grasses and legumes were planted in the field at Uyole, the grasses being either in pure stands or in mixtures with the different legumes. Due to seed shortage plot sizes had to be reduced to 9 m^2 unreplicated and arranged in a split-block design. Weed control was done by the hand hoe during the first year of establishment and depending on the growth habit of the species, no weeding was carried out during the second year.

Centro was very slow to establish compared to most other legumes. Stylos showed good performance during the first year only while lucerne was completely eliminated by most grasses. Though suited to the drier inland regions Buffel grass cv Biloela performed adequately at an altitude as high as 1800 m.a.s.l.

All grasses proved to be drought resistant and although they were susceptible to night frosts in July/August they recovered rapidly. An exception was *Urochloa mosambiscensis* which did not recover after the fourth year. In addition *Urochloa* was completely shaded and killed by both *Desmodium* and *Neonotonia* spp. Most grasses were able to control weeds effectively except *Urochloa, Paspalum plicatulum* cv Bryan and *Setaria sphacelata* cv Narok. *Paspalum* was also completely shaded by both *Desmodium* spp. or Silverleaf. The only grasses that tended to show a good balance with the desmodiums were *Brachiaria decumbens* and *Setaria sphacelata* cv Kazungula.

Among the legumes only Siratro, the *Desmodium* and *Neonotonia* spp. showed promise. Legumes like Centro, clovers and the stylos were all suppressed by the grasses. Despite the promise shown by *Neonotonia*, the legume failed to flower at Uyole and at Mitahila (1055 m.a.s.l.). One Centro has proved to flower in three months from planting at that altitude.

Further grass evaluation in pure swards are currently being done on Rompha grass, canary grass,' *Entclasia imbricata, Cynodon nlemfuensis*, Cocksfoot and *Panicum coloratum*. They are compared with Rhodes grass and *Themeda triandra* as standard checks. With the legumes, further evaluations include *Crotalaria intermedia*, Archer dolichos, Berseem, *Rhynchosia* and *Neonotonia wightii* (Mbeya type).

Evaluation in terms of animal production has just been started at Uyole and there are indications that on a fertilized Rhodes/Desmodium mixture a grazing pressure of 32 animals/ha can be used without effecting milk production.

Perennial Fodder Crops

The major problem the small- and large-scale farmers face in the highlands is shortage of green fodder during the six-month dry season. To solve this problem fodder crops have been introduced and evaluated. These are discussed below.

Napier grass

This crop was introduced at Uyole in 1971 from the surrounding districts in Mbeya Region. Evaluations at the Centre showed it to be high yielding. Due to the increase in fertilizer prices, the evaluation included comparisons with Silverleaf Desmodium. Three-years' average data are shown in Table 6.

This kind of evaluation indicated benefits for the mixture in dry-matter yield which could help farmers release inorganic fertilizers for other crops. For two consecutive seasons a chemical analysis was done on the first cut of the mixture, and it was clear that protein content increased with the inclusion of the legume as indicated in Table 7.

Table 6. Dry-matter yield (kg/ha) of Napier grass - Desmodium mixture at two nitrogen levels.

Mixtures	Nitrogen application kg N/ha/season 0	80N	Mean
Napier grass alone	5050	10140	7590
Napier grass + Desmodium within rows	12580	15730	14150
Napier grass + Desmodium between Napier rows	11880	15440	13650

Source: Myoya (1980).

Table 7. Crude protein content of fodder Napier when fertilized or grown in association with Silverleaf Desmodium.

Fodder type	Crude protein (on % DM basis) 1973/74	1974/75	Means
Without N, Napier alone	5.4	4.3	4.9
40 kg/ha N, Napier alone	5.9	4.6	5.3
Without N, Napier + Desmodium	12.9	11.4	5.3
40 N/ha N, Napier + Desmodium	10.4	9.8	10.1

Applications of 40 kg N resulted in a small crude protein increase as compared to the legume mixture effect. Though the crop was hit by night frosts in July, it recovered at the end of August. Growth commenced immediately, and it became available for feeding in the October-November period.

Due to much interest in Napier fodder, four new cultivars were introduced from Kitale, Kenya in 1975 and dry-matter yield assessed for five consecutive years. Only average data is shown in Table 8 (1977-1981). Despite the high yield obtained from Gold Coast, which almost approached that of Mbeya ecotype, its hairiness limits its use as they produce skin irritations especially when used under cut-and-carry. French Cameroons produced relatively high yields and large amounts have already been planted by the surrounding small-scale dairy farmers. The crop has successfully been introduced in other localities like Mbozi (1525 m.a.s.l.), Nkundi in Sumbawanga (1750 m.a.s.l.) and Mitalula (1055 m.a.s.l.).

Table 8. Dry-matter yield of different Napier grass cultivars at varying nitrogen application rates (kg/ha).

Nitrogen level (kg N/ha)	Cultivars				
	Gold Coast	French Camerouns	Mlingano	Ethiopia	Mbeya
0	3720	3860	1910	1400	3850
60	4950	5890	2430	2290	5960
120	7780	8260	4580	3800	6910
240	14290	13260	6380	7970	15800

Russian Comfrey *(Symphytum peregrinum)*

This is reported as a suitable fodder crop for cattle, horses, sheep, pigs and poultry. Observations at Uyole confirm Strange's (1959) findings that it is never touched by cattle when freshly cut. The crop was introduced from Tengeru in Arusha in 1977. Dry-matter yield averaged 6 t/ha under nitrogen applications of 160 kg N/ha. A chemical analysis of the crop indicated 17.9% crude protein, 10.9% crude fibre, 3.2% crude fat and 24.4% ash all on dry-matter basis.

Lucerne: Among the perennial fodder legumes that have received much attention at Uyole is lucerne. Initial work in Tanzania started in Northern Tanzania where the cultivar Hairy Peruvian was compared with the cultivars Saladina and Hunter River. Work at Uyole started in 1971 with introductions of cultivars Tuna and Du Puitis (Anon, 1972) from Sweden. Due to poor germination and heavy weed competition these cultivars were lost.

During the 1974/75 season 16 lucerne cultivars were re-introduced from Sweden. Evaluations based on dry-matter productivity showed that at the onset of the dry season good quality hay can be produced from lucerne.

However, during the 1973/74 season the cultivar Hairy Peruvian was planted in replacement series with Rhodes grass cv Pokot and nitrogen application included in order to measure the possible yield contribution of the mixture. During the first season a seed rate mixture of 3.5 kg Rhodes grass and 4 kg lucerne produced the highest yield. The two-year average data is shown in Table 9.

The results not only demonstrated the advantages of the mixture but also indicated that lucerne benefited from small quantities of nitrogen application. Without nitrogen the mixture had a 12-14% CP content while with nitrogen application this was 13.9-15.8% CP, showing a small increase. Further evaluations stopped due to seed unavailability. At this altitude (1800 m.a.s.l.) there were not enough pollinators for the crop and hence no seed yield.

Table 9. Dry-matter yield of Rhodes-lucerne mixture, kg/ha.

	Nitrogen application, kg N/ha		
	0	60	Means
Pure Rhodes	3860	8210	6035
Rhodes lucerne	6890	9940	8415
Pure lucerne	6070	8260	7165

Source: Anon (1977, 1980).

Annual Fodder Crops

These are short-term crops that cannot only be used to overcome seasonal feed shortages but also as main producers of roughage. They can be used as pioneer crops in new lands and they can easily be integrated into mixed crop-livestock enterprises. They can be used for direct grazing, made into silage or fed as green chop.

Oats (*Avena sativa*)

At higher altitudes in the highlands cool-season crops like oats can be grown. During 1970/71, ten oats cultivars were introduced from Sweden, Finland and Holland. These were planted in single rows and their seed yield potential assessed. Most cultivars showed a vigorous vegetative growth, but due to disease attack very few panicles were formed and hence low seed yields were recorded (Table 10). Comparisons were made with the locally grown cultivar "Suregrain" from Canada which was introduced at Uyole in 1970 for use as a companion crop in the establishment of grass legume pastures, silage and green fodder production.

Table 10. Seed yield of different oats cultivars at Uyole, dry-matter yield and rust score trial.

	1970/71		1971/72	
Cultivar	Days to heading	Seed yield (kg/ha)	Dry-matter yield (kg/ha)	Rust score[a] (1-70)
SOIL II	-	-	5,400	5
Pendek	104	250	5,720	-
Hannes	109	500	-	-
Same	104	130	-	-
Nil	83	420	5,380	3
Titus	104	310	4,570	6
Stormogul	-	170	-	-
Sorbo	-	130	4,330	10
Linda	104	780	5,920	6
Condor	111	740	5,650	5
Selma	103	760	6,620	5
Suregrain	93	480	4,050	0
Nina	-	-	5,380	5

[a] Crown rust assessment: 0 = No attack; 10 = Very severe attack.

During the following season two new cultivars Nina and Sol II were added to the evaluation and the dry-matter yield measured at milk ripe stage. Rust assessment was made on all cultivars and there was an indication that most introduced cultivars had severe to very severe attack. The locally grown oats had no attack at all. These assessments tended to show that higher seed and dry matter yielding oats can be obtained but their problem was attack by crown and stem rust, resulting in a complete crop loss in cooler years.

During the 1975/76 season 363 spring oats cultivars were introduced from the Royal Veterinary and Agricultural University, Sweden. These were planted in single rows whose purpose was to use intra-varietal diversification in the form of multiline cultivars to supplement the conventional resistant cultivars as part of the programme of crown rust control. The cultivars that did not set seed due to crown rust attack were abandoned in the first season. Only 25 cultivars were then selected based on resistance to crown rust. These were grown for four consecutive seasons and their mean dry matter, seed yield and other characters are as shown in Table 11. The cultivars Palestine and Orient were outstanding for earliness of maturity which was under 100 days. Based on crown rust assessment, Suregrain was the most resistant cultivar followed by C. Iowa, Clinton, Gidgee, C.I.3821 and Ballidu.

During the 1982/83 season, the locally adapted Suregrain cultivar was tested for its nutritive quality in comparison with Napier grass (Table 12). Two trials were conducted at different growth stages of oats.

The results showed oats to be highly digestible, but digestibility falls with age. The normal harvest stage for Suregrain is about 135 days where it could be at milk-ripe stage.

Due to crown rust attack on the oats, different Triticale cultivars have been introduced, and assessments are in progress. So far, it has been shown that most Triticale cultivars are resistant to rusts and they give much higher dry-matter yield. Triticale cultivars have also shown a much higher seed-yield potential (Table 13). Most oats and Triticale cultivars outyielded the standard cultivar Suregrain.

Table 11. Dry matter, seed yield, 1,000 kernel weight and hull content of selected oats cultivars (four-year average data) (1978-1981).

Cultivar	DM (kg/ha)	Seed yield (kg/ha)	Months to forage harvest	1,000 kernel wt (g)	Hull content (%)	Rust attack (0-10)
Ajax	4100	217	4.9	24.3	30.9	7.6
C. Iowa	3340	172	4.9	21.6	31.4	3.4
Clinton	3400	488	5.1	27.6	40.2	4.3
M.H. Iowa	4010	260	5.1	24.6	48.2	5.2
N.I. fra. Iowa	3770	208	4.2	22.4	33.6	4.7
Gidgee	3880	480	4.6	30.5	34.1	4.3
Mulga	3260	314	5.3	32.0	36.8	6.0
Kareela	3420	164	4.9	22.9	36.8	4.5
Dale	3080	470	3.5	29.9	35.4	4.7
Orient	3100	363	3.2	28.4	39.0	5.1
Ballidu	3180	215	3.9	18.6	33.0	4.3
Fulghum	3250	427	4.2	28.7	43.0	4.5
Early Burt	3200	365	4.6	28.6	37.5	5.3
Palestine C.I.3600	2980	373	3.9	35.4	38.3	7.7
C.I. 3920	2680	395	4.6	33.3	41.5	7.3
C.I. 3821	3440	223	4.6	30.7	50.4	4.2
A. abyssinica	2950	189	4.6	30.3	39.7	6.2
A. abyssinica	2800	496	4.6	36.9	32.9	9.0
Shmya	2970	163	5.1	21.7	46.7	4.8
Daubeney	3910	340	5.1	34.1	29.4	6.7
Palestine	3010	377	3.2	33.3	47.2	5.7
C.I. 2424	3220	298	4.9	21.6	40.0	4.9
Fulgrain	3480	596	5.3	31.9	35.0	6.5
Fulgrain (coker)	3060	200	4.2	30.2	35.4	5.5
C.I. 7488	3720	403	4.2	32.2	32.0	7.5
Suregrain	2700	260	4.6	31.5	33.4	0.5

Table 12. Dry-matter digestibility and intake of oats and Napier grass at different growth stages.

Parameter	Trial I: Oats 82 days	Trial I: Oats 156 days	Trial I: Napier grass	Trial II: Oats 97 days	Trial II: Oats 171 days	Trial II: Napier grass
Digestibility, %	64.5	55.2	32.9	54.7	49.8	47.1
intake ($g/kg\ W^{0.75}$)	77.0	41.0	34.9	47.2	50.0	45.8

Table 13. Comparison of selected forage oats and *Triticale* cultivars for dry-matter and seed yield (kg/ha).

Species	Cultivars	Dry-matter yield (kg/ha) 1983	1984	1985	Mean	Seed yield kg/ha 1983
Oats	Suregrain	2930	5900	7650	5490	300
	C.I. 3920	4350	6910	8530	6600	730
	C.I. 7488	4470	5340	8240	6020	1030
	Avena abyssinica	4850	4680	87[illegible]0	6100	900
	Palestine	4670	6020	7180	5950	800
Triticale	T11 - 152	5520	4690	7800	6000	1630
	T11 - 234	5640	4920	7370	5980	2370
	T11 - 158	5780	5040	8980	6600	1540
	T10 - 9	5800	6760	7850	6800	1450
	T10 - 211 - 8	5740	5620	9230	6860	1170

Sorghum

No sorghum germplasm introductions were made at the Centre until 1982 when seed of *Sorghum almum* cv Sugardrip was obtained from Australia. Since it is a crop that can be rationed, it was grown either in pure stand or in mixture with Greenleaf and Silverleaf Desmodium, Seca Stylo, Cook Stylo, Siratro and Tinaroo Neonotonia. Average data for two seasons indicated sorghum to give 8 tonnes DM per hectare in pure stand when cut three times per season while the yield was drastically reduced in mixtures with legumes as indicated by the data in Table 14. Such mixtures proved a failure during the third season as most sorghum plants were completely smothered by the legumes.

Table 14. Dry-matter yield of *Sorghum almum* cv Sugardrip when grown in pure stand or in mixture with different legumes.

Mixtures:	Sorghum yield kg DM/ha	Legume yield kg DM/ha	Total
Pure sorghum	8090	-	8090
Sorghum + Seca stylo	1330	1700	3030
Sorghum + Cook stylo	390	1270	1660
Sorghum + Siratro	710	1110	1820
Sorghum + Silverleaf Desmodium	410	12780	13190
Sorghum + Greenleaf Desmodium	170	16670	16840
Sorghum + Neonotonia	1030	7870	8900

Lupines

The introduction of lupines at Uyole was aimed at improving soil fertility through crop rotations, increasing quality of the available fodders and supplying green feed during the early to mid-part of the dry season. During the 1971/72 season two species of lupines (*Lupinus albus* and *Lupinus angustifolius*) were introduced from Sweden and subjected to a planting dates trial the results of which are presented in Table 15.

In this particular evaluation it was shown that lupines could be planted as late as mid-March without affecting either seed or forage yield. Lupines planted mid-March would be ready for feeding in mid-July under Uyole conditions. For grain production, late planted lupines grew longer into the dry season resulting in much shattering of the seed.

Having established that lupines could help solve feed quality and supply problems, more cultivars were introduced in 1974 for further evaluation. Results showed the *L. albus* cultivar Kulina to be the most outstanding. The most promising ten cultivars are currently being further tested for dry-matter yield and alkaloid content.

Table 15. Dry matter, seed yield (kg/ha) and 1000 kernel weight of two lupine species under different planting dates.

Planting	DM yield kg/ha	Seed yield kg/ha	1000 kernel weight (g)
1. Blue sweet lupines *L. albus*			
2.12.71	9500	1565	118.6
22.12.71	7330	1077	130.6
17.1.72	7930	67	-
1.2.72	8360	358	148.8
19.2.72	9860	-	-
10.3.72	6890	450	-
2. White Sweet Lupine (*L. angustifolius* cv Uniwhite)			
2.12.71	9180	1047	116.3
22.12.71	6070	962	138.5
17.1.72	7780	617	144.5
1.2.72	8320	973	157.1
19.2.72	9160	865	157.1
10.3.72	9270	1300	-

Source: Anon (1973).

Fodder-Sugar Beets

Germplasm evaluation started in 1971 at Uyole with the introduction of two beet cultivars (Aring Barres fodder-beet and Triumf sugarbeet) from Sweden. The sugar beet Triumf outyielded the fodder beet Aring Barres in a progressive harvesting date trial (Table 16). The dry-matter content of leaves varied from 9% for the first harvest data to 60% during the last for both cultivars; while that of roots varied from 9% to 19%. This trial demonstrated the advantages of growing beet for fodder. When planted in January the crop can be left in the field up to November without very much affecting the yield.

Thirty-three cultivars of fodder beets and 42 cultivars of sugar beets were further introduced. The sugar beets gave much higher yields than fodder beets, and in most cases sugar beets had a dry-matter content of above 25% while fodder beets had below 20%. There was a tendency for declining yield with the progressing years which could probably be due to inadequate phosphorus fertilization which was at the rate of 44 kg P/ha. Beets have been reported from California to require rates of between 49.3 kg to 148 kg P/ha (de Geus, 1973). Sugar beets gave yields ranging from 3-7 t DM ha, whereas the fodder beets gave a yield range in excess of 6 t DM/ha. The major problem encountered with this crop is seed production as the plants cannot bolt in Tanzania.

Table 16. Dry-matter yield of fodder-sugar beets under delayed harvesting at Uyole (kg/ha) roots and leaves (planted in January 1971).

Harvesting date	Aring Bares	Triumf
5/4	4360	5630
3/5	6580	9330
1/6	9340	12390
1/7	8100	11890
2/8	7520	10890
2/9	8480	10370
1/10	8160	11880
8/11	7670	10250
Means	7526 SD ± 1506	10329 SD ± 2154

Fodder Shrubs

Leucaena

This is one of the first fodder shrubs to be introduced at Uyole. Introductions started in 1981 from coffee plantations in Mbozi district where it was planted as a shade tree for coffee. Further introductions were made in 1982 from Australia. These were var. Peruvian ex. Aust. Yates; K28; K8; Cunningham; var. Peruvian Ex. Tengeru, Kongwa and Morogoro. All the introduced cultivars were shrubs except that collected from Mbozi which grows to 7 m high when undisturbed. So far no data have been collected on dry-matter yield, but from observations var. Peruvian Ex. Aust. Yates has a more prolific branching habit and is leafier. Seed production of all cultivars is quite good.

Galega orientalis (Goats rue)

This particular shrub legume was introduced from Helsinki University, Finland in 1986. Growth during the first year was very slow. Information from Helsinki (Varis, 1986) indicates that its quality can exceed that of lucerne. Observations on it are taking place.

Desmodium ransonii

This legume was introduced from West Kilimanjaro in 1984. It has proved to be a non-branching legume that grows to a height of about 8 m. It has a very weak stem and even at that height it is less leafy.

CONCLUSION

The suite of germplasm introduced and evaluated is wide. It ranges from the annual perennial fodders of temperate origin to the tropical/subtropical grasses and legumes including shrubs/trees. The promise of some of the species has to be matched with feed requirements of the existing livestock production systems in the Southern Highlands region of Tanzania. Research efforts have logically to be directed towards studying the animal production potentials of some of these forage and fodder germplasm.

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A REVIEW ON EVALUATION AND AGRONOMY OF PROMISING LUPINE VARIETIES IN KENYA

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Abstract

This review deals with a series of agronomic and evaluation work on promising lupine varieties in major agroecological zones of Kenya. The trials examined regional performance of different varieties of lupine and the effects of inoculation and phosphatic fertilization. Results from early observation trials indicated that lupines performed better in the medium and high altitude, high potential areas. Other areas appeared unsuitable for this crop partly due to inadequate moisture levels.

Reported observations showed that cultivars Unicrop and Ultra were early maturing and were relatively shorter in height compared to Uniwhite and Uniharvest both of which were taller and later maturing. Moreover, further work revealed that cultivars Uniharvest, Ultra and Uniwhite had higher grain yield and higher protein (42.8%, 40.7% and 35.8% respectively) compared to Unicrop (31.0%). Cultivar Ultra was the highest seed yielder. Only small increases in seed yield and quality were reported when inoculants and phosphatic fertilizers were used suggesting that these treatments may not be beneficial under certain conditions.

INTRODUCTION

Lupines are annual or perennial legumes belonging to the genus *Lupinus* which contains 250 species (Highes *et al.*, 1952). Most of these are native to America. The large-seeded species of commercial importance, however, are all native to the Mediterranean basin in Europe. These include blue lupine (*L. angustifolius* and *L. hirsutus)*, white lupine (*L. albus*) and the yellow lupine (*L. luteus*). Others are the Spanish lupine (*L. hispanicus*) and Texas lupine (*L. mutabilis*) which have been used for more than 3000 years as a subsistence crop in the Andean Highlands (Lees, 1979). Some of the cultivated lupines are bitter and unpalatable but excellent producers of nitrogen.

In Kenya, there are two species of sweet lupines whose agronomy and nutritive evaluation has received considerable attention. These are the blue lupine cultivars Uniwhite, Uniharvest and Unicrop and the white lupines represented by the cultivar Ultra (Wanjala, 1979). All of them are annual in nature. These varieties with high foliage, grain yields and high crude protein content were shown to take 4-7 months to mature depending on variety (Gladstones, 1970; Wanjala, 1979). The main objective of conducted work on lupine in Kenya was to establish a cheap source of protein as a concentrate for livestock supplementation. Trials undertaken at the National Agricultural Research Station, Kitale, included testing the adaptability of lupine varieties in different agroecological zones (Bauer and

Oketch, 1976), the observation of physiological characters of lupine varieties grown under uniform conditions (Kusewa *et al.*, 1977), the comparison of herbage dry-matter yield (Kusewa *et al.*, 1980, 1981) and the investigation on the effect of phosphatic fertilizers and inoculation on seed production of the lupine variety Ultra (Kusewa *et al.*, 1980, 1981).

RESULTS

Lupine Regional Adaptability

Based on rainfall and altitude Bauer and Oketch (1976) have reported on the adaptability of lupines in nine sites in Kenya (Table 1). The lupines were planted at a recommended spacing of 50 x 30 cm, Bauer and Oketch (1975) in unreplicated plots.

Table 1. Performance of lupine varieties in different agro-ecological zones of Kenya.

	Altitude (m)	Rainfall[2] (mm)	Height (cm)	Variety	Seed yield t/ha	Remarks
Molo	2740	1015-1270	110	Ultra	-	Slow to swell
Eldoret	2130	1015-1270	119	Ultra	1.8	Lodging
Nyandarua[1]	2331	760-1015	100	Ultra	-	-
Kitale	1980	1015-1270	60-140	Ultra	1.7	
				Uniharvest	2.2	
				Uniwhite	1.8	Lodged
				Unicrop	1.2	Shortest
Kakamega	1580	1780-2030	87	Ultra	1.4	Seed shattering
Embu	1460	760-1015	79	Ultra	0.81	
Katumani[1]	1680	510-760	41	Ultra Uniwhite Uniharvest Unicrop	-	All poor and diseased
Kiboko[1]	1000	300-650	39	Ultra, Unicrop	-	Pods were weak
Mtwapa[1]	12	1015-1270	25	Ultra, Unicrop Uniwhite, Uniharvest	-	Poor and diseased

Source: Bauer and Oketch (1976).
1 Seed yield not available.
2 Source of mean annual rainfall: *National Atlas of Kenya*, third edition, 1970.

Medium and high altitude, high potential regions such as Kitale, Molo, Eldoret, Kakamega and Embu proved to be the most promising sites for growing sweet lupines. Hot and dry areas such as Katumani and Kiboko as well as the hot and wet areas such as Mtwapa (Mombasa) proved unsuitable. There are indications that for better yields, lupines need 5 months free of serious moisture stress and mean monthly maximum temperatures ranging from 15 to 25°C (Wanjala, 1979). These conditions are typical of the areas where lupines produced favourable results.

Physiological Development of Lupine Varieties

Physiological development of four lupine varieties grown under uniform conditions was observed at Kitale (Kusewa *et al.*, 1977). The four lupine varieties Uniwhite, Unicrop, Ultra and Uniharvest were inoculated with group "G" inoculant before planting. Single superphosphate fertilizer at the rate of 40 kg/ha P_2O_5 was applied at planting. A spacing of 50 x 30 cm was used with two seeds per hill at planting.

It was shown (Table 2) that Unicrop and Ultra were early maturing and were short and medium in height, respectively. On the contrary, Uniwhite and Uniharvest were tall and late maturing. Uniwhite was more susceptible to lodging than any of the other varieties studied. Field observations also indicated that Unicrop was the most susceptible to powdery mildew. Considering seed weight, Ultra had a higher weight per 100 seeds than all the other varieties. It also had more pods/plant than the others.

Table 2. Physiological development of lupine varieties.

Observation	Variety			
	Uniwhite	Unicrop	Uniharvest	Unicrop
Days to germinate	5	5	5	5
Days to 80% flowering	125	49	91	49
Lodging (%)	30	0	10	15
Days to maturity	202	120	202	150
Shattering of seed (%)	30	5	5	5
Plant height (cm)	140	60	115	110
Pods per plant	28	19	27	45
100 seed weight (g)	17.3	19.3	17.5	43.5

Source: Kusewa *et al.* (1977).

Productivity and Evaluation of Lupine Varieties

Kusewa *et al.* (1980, 1981) conducted a trial at Kitale to determine herbage dry matter, seed production and nutritive value of four lupine varieties; Unicrop, Uniwhite, Uniharvest and Ultra. They were planted under recommended establishment practices similar to those of the physiological development study. The lupines were harvested at three stages of growth i.e. 2, 3 and 4 months after establishment. A single plot was included per variety for the determination of seed at physiological maturity.

Significant differences (P<0.01) were observed in both herbage dry-matter and seed yield among varieties and harvesting stages (Table 3). Variety Ultra was outstanding in both herbage and seed yield. During 1980, maximum herbage yield for Ultra, Uniharvest and Uniwhite were obtained when they were cut at four months but highest yield for Unicrop was attained at three months. In 1981, however, all the varieties had the highest herbage yield when harvested at four months. Crude protein (CP) values and *in vitro* digestibility values (Table 4 and 5) were higher in the grains than in the herbage in all the four lupine varieties investigated.

Table 3. Performance of lupine varieties harvested at different stages.

	Herbage DM production kg/ha							
	2 months		3 months		4 months		Seed yield (kg/ha)	
Harvesting stage	1980	1981	1980	1981	1980	1981	1980	1981
Unicrop	760	140	1612	610	1260	990	350	260
Uniwhite	510	120	2764	410	3074	1620	947	890
Uniharvest	615	180	2227	820	4426	2590	750	1190
Ultra	692	166	3400	2180	4300	6180	3344	4000

Source: Kusewa *et al.* (1980, 1981).

Table 4. Effect of stage harvesting on the crude protein content of lupine varieties.

	Harvesting stages (CP %)						Seed at physiological maturity
	2 months		3 months		4 months		(CP %)
Variety	1980	1981	1980	1981	1980	1981	1981
Unicrop	21.9	25.4	16.4	26.8	14.3	23.9	31.0
Uniwhite	19.0	25.0	17.8	28.6	14.3	8.2	35.8
Uniharvest	21.0	20.4	18.9	10.7	17.3	19.6	42.8
Ultra	20.2	16.6	15.9	23.5	14.3	13.6	40.7

Source: Kusewa *et al.* (1980, 1981).

Table 5. Effect of stage of harvesting on the digestibility values of lupine varieties.

Variety	D-value	D-value	D-value	D-value
Unicrop	62.2	65.2	57.6	85.5
Uniwhite	64.3	65.0	56.0	88.8
Uniharvest	62.7	64.1	54.7	88.7
Ultra	66.2	67.5	74.2	84.0

Source: Kusewa *et al.* (1980).

Phosphate fertilizer and inoculation requirements of lupines

A trial conducted by Kusewa *et al.* (1980, 1981) examined the seed production of lupine cv Ultra when inoculated and fertilized with phosphates at the rates of, 100, 200, 300 kg/ha P_2O_5. Inoculation resulted in more nodule formation per plant whereas phosphate fertilizer application did not have any effect on nodulation between the inoculated and non-inoculated lupine plants (Table 6). Differences in seed yield and percent protein content were not significant suggesting that inoculation and phosphatic fertilization were not beneficial under Kitale conditions.

DISCUSSION

The four sweet lupine varieties tested were shown to do well in medium and high altitude, high potential areas of Kenya. The lupines did not do well in hot and dry areas because of the moisture stress. These results are in agreement with those of Heath *et al.* (1975) who had reported that lupines required cool weather for best development. Savile and Wright (1958) reported that sweet lupines grow at altitudes between 2225 and 2743 m and bitter lupines from 1981 to 2743m. It would, however, appear that sweet lupines can still do well at lower altitudes than those recommended by Savile and Wright as evidenced by studies conducted by Heilbutch (1952); Poultney (1963); Bauer and Oketch (1976) and Wanjala (1979). They reported promising results in Kitale at a lower altitude of 1980 m.

The cultivar Ultra outyielded other varieties (Table 3) due to development of numerous pods and heavier seeds. This result would appear to contradict earlier observation (Table 1) where Ultra was outyielded by Uniharvest and Uniwhite. However, experiments conducted by Bauer and Oketch (1975, 1976); Kusewa *et al.* (1977) and Wanjala (1979) confirm that Ultra is superior to the others in seed yield. Two farmers in Kitale reported a seed yield of 780-1100 kg/ha in 1951 and 780-1900 kg/ha in 1952 for sweet blue lupines (Heilbutch, 1952). This is within the range reported in Table 1.

Table 6. The effects of inoculation and phosphate fertilization of lupi cv Ultra.

Year		Inoculation Kg/ha P(2)O(5)					Non-inoculation Kg/ha P(2)O(5)					S.E. of means	
		0	100	200	300	Mean	0	100	200	300	Mean	Inoc.	Fert. rates
	Nodules/plant	23	23	27	20	23	17	22	20	26	21	1.3	1.7
1980	Seed yield t/ha	3.37	3.25	2.97	3.12	3.18	3.59	3.45	3.25	3.12	3.35	0.05	0.17
	CP %	30.2	32.3	31.5	29.8	31.0	30.4	29.3	28.9	33.6	30.6		
	Nodules/plant	17	24	23	23	22	15	19	17	18	17	1.2	1.7
1981	Seed yield t/ha	3.92	3.85	4.01	3.81	3.90	3.82	3.73	3.62	3.63	3.70	0.1	0.2
	CP %	38.2	45.4	38.5	41.2	40.8	38.9	35.3	41.9	37.1	38.3		

Source: Kusewa et al. (1980, 1981).

Lack of response of sweet lupine varieties to inoculation and phosphate fertilization indicates that lupines can still be grown in Kitale without such treatments. The lack of response could be attributed to the fact that soils in Kitale have levels of phosphate adequate to support lupine growth. The results agree with those of Henderson and Preston (1959) who recommended that application of phosphate should only be done on soils of very low fertility. Work by Bauer (1976) on lupine cv Ultra gave similar results.

Inoculation should have resulted in greater nodulation hence higher seed yields. However, this was not so and could be attributed to ineffective nodulation. This argument is in line with that of Henderson and Preston (1959) who reported good nodulation of uninoculated crops in most areas of Kenya, although they noted that most of the nodules were ineffective. Work carried out by Wanjala *et al.* (1983) in one farmer's field showed a significant seed-yield response of sweet lupine cv Ultra to inoculation but not to phosphate fertilizer. A more comprehensive study by de Souza (1969) when working on blue lupines found effective natural nodules at twelve sites and no natural nodulation at nine sites.

Experiences gained from this study show that there is need for lupine variety testing trials to be conducted in different ecological zones for herbage and seed yield. There is also need for phosphate and inoculation studies to be conducted in a wide range of sites. Future agronomic interventions of lupine studies should involve a study on the relationship of critical elements like sulphur and molybdenum with seed production and investigations on the effect of planting dates on seed yield for both early and late maturing varieties to avoid seed losses during wet weather. Other aspects to be considered should be intercropping lupine with food crop or other forages with the aim of maximising the utilisation of the ever-diminishing land holdings in the high potential areas.

CONCLUSION

The high dry-matter yield, percent crude protein and high D-values especially in seed for the various lupine cultivars indicate that there is great potential for the utilisation of lupines as a livestock feed supplement. Further studies aimed at the utilisation of sweet lupines as a feeding material will elucidate the importance of these lupines in the livestock industry.

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THE EFFECT OF LUPINE/MAIZE MEAL SUPPLEMENTATION ON THE PERFORMANCE OF LACTATING FRIESIAN COWS

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Abstract

Two groups each of five lactating Friesian cows were supplemented with varying proportions of lupine and maize meal. The five rations contained lupine and maize meal percent proportions, respectively as follows: A(100,0), B(75,25), C(50,50), D(25,75) and E(0,100). The milk yield and its quality for each cow were determined along with supplemental intake and percent crude protein (CP).

The rations had no effect on the milk butterfat, solids-not-fat, calcium, phosphorus and total solids. Animals on ration D(17.4% CP) had the highest milk yield of 15 kg/day and an intake of 3.9 kg/day. Ration E with 10.0% CP gave the highest intake at 4.0 kg/day with a yield of 13.4 kg Fat Corrected Milk (FCM) per day. This production was superior to that recorded for rations A, B and C. Invariably, ration A with the highest percent CP of 32.7 gave the least intake of 2.0 kg/day and the least milk yield of 10.3 kg FCM/day. This unexpected observation was attributed to some inherent factor in the lupine meal that negates intake with the resultant effect of lowering milk yield.

INTRODUCTION

In most smallholder dairy systems in the high potential areas of Kenya, provision of enough feed to lactating animals is a major constraint to production. Fresh herbage and crop residues fed during the dry season are generally of low quality and hence contain substandard energy and protein levels that can hardly meet maintenance requirements of lactating cows. In these circumstances, lupine grain could prove suitable as a feed supplement (Kenney, 1980). As well as having a comparatively high protein content (over 30% in dry matter), lupine is easy to feed and convenient to store for a considerable period of time.

Commercial feeds manufactured and compounded by some feed industries form the bulk of the supplements in dairy enterprises. ...se are expensive for the average Kenyan farmer, hence the need ... have supplement substitutes that can provide adequate energy ...d protein levels that do meet production requirements of lactating animals. The cost of lupine and its availability and value as a feed is such that it could be mixed with other cereal grains particularly maize for supplementary feeding. A grain with such a high protein content could be suitable as a supplement for lactating cows for which a diet with a protein content of about 16% is recommended for maximum production (NRC, 1978).

Protein ingredients in most supplements are the most expensive and hence pose major problems in most on-farm rations;

this is because humans compete for the same for food. This, however, is not the case with lupine which is currently being used solely as feed. This study which involved the feeding of lupine (*Lupinus albus* cv Ultra) and maize meal was designed to solve the supplementation problem of nearly 20,000 farmers (Stotz, 1983) located mostly in the Kenyan highlands.

Lupine, however, has shortcomings which include lupinosis known to cause liver disfunction through the damaging of liver tissues. The dangers of lupinosis have not been reported when seed is fed as a concentrate to ruminants, but was reported on the non-ruminants by Godfrey *et al.* (1985) and Wanjala (1979).

Little work has been reported on the performance of dairy cows when supplemented with lupine alone or when incorporated in high energy diets. The primary objective of this trial was to study the effect of supplementing varying proportions of maize and lupine meal on the milk yield of lactating Friesian cows.

METHODOLOGY

The lactating Friesian cows, divided into two groups of five, were selected based on stage of lactation (animals in second or third lactation being preferred), average yield of Fat Corrected Milk (FCM), days postpartum and liveweight. The cows were then randomly assigned to five treatments containing varying proportions of maize and lupine meals. The percentage proportions of the two ration ingredients were A(100,0), B(75,25), C(50,50), D(25,75) and E(0,100) of lupine and maize meal, respectively.

A change-over design in two 5 x 5 latin squares was used in the study. For each group of cows there was an adjustment period and a collection period of 14 days and 7 days, respectively. The cows were grazed on good quality *Chloris gayana* (Rhodes grass) pasture with supplementation being done daily during milkings at 08:00 and 16:00 hours. About 4.0 kg of each ration was supplemented daily to each animal.

For each cow, the quantity of FCM produced daily was recorded. Samples of milk were taken twice a week during the collection period. The Gerber method was used in the determination of percent butterfat, on a portion of the sample, immediately after milking. The remaining sample was bulked for each cow within each period and later analysed for milk protein (CP), solids-not-fat (SNF), total solids (TS), calcium and phosphorus.

RESULTS

Milk Yield and Quality Assessments

A summary of the average milk yield and its quality values are shown in Table 1. Milk yield expressed on a fat corrected basis was highest (15.0 kg/day) for cows supplemented with treatment D, followed with treatment E which gave 13.4 kg FCM/day. Non-significant differences (P>0.05) were observed among treatments

Table 1. Summary of average milk production and milk quality values.

Experimental rations	Milk yield (kg)	Milk quality (%)d					
		CP[1]	BF[2]	SNF[3]	Ca	P	TS[4]
A	10.3[c]	27.9[a]	4.0	7.2	.88	.95	11.2
B	11.5[c]	26.7[b]	3.9	7.4	.91	.89	11.3
C	10.7[c]	25.8[b]	4.0	7.4	.86	.88	11.4
D	15.0[a]	24.5[c]	4.1	7.3	.87	.86	11.4
E	13.4[b]	24.1[c]	3.7	7.3	.91	.87	10.9
SE	0.5	0.3	0.1	0.1	.02	.03	0.1
LSD	1.4	0.9	NS	NS	NS	NS	NS
CV %	8.4	2.5	6.8	1.8	5.4	6.5	6.8

abc Means in the same columns with different superscripts are significantly different.
d Averaged for each ration between experimental periods.
1 Crude protein
2 Butterfat
3 Solids-Not-Fat
4 Total solids

A, B and C (10.3, 11.5, 10.5 kg FCM/day, respectively). The milk protein from cows fed on treatment ration B and C were higher ($P<0.05$) than that of milk from cows fed on treatments D and E. Other milk quality factors (SNF, BF, TS, Ca, P) did not show any differences ($P>0.05$) among treatments.

Supplement Quality Analyses and Intake

The per cent CP content and intake values of the various ration formulations are presented in Table 2. Ration A had the highest CP ($P<0.05$) value of 22.7 but the least intake ($P<0.05$) of 2.0 kg/day. The results showed a declining trend in intake with increasing ration CP content.

Table 2. Crude protein and intake values of the concentrate rations.

Experimental rations	% CP						Intake (kg/day)
	Periods						
	I	II	III	IV	V	Mean	
A	33.5	32.9	34.1	31.9	31.1	32.7[a]	2.0[c]
B	27.9	26.9	25.9	28.1	27.2	27.2[b]	3.2[b]
C	24.6	23.9	21.9	23.2	21.1	22.9[c]	3.5[a]
D	18.6	16.8	16.9	17.2	17.6	17.4[d]	3.9[a]
E	9.7	9.6	10.1	10.5	9.9	10.0[e]	4.0[a]
				S.E.		0.4	0.2
				LSD .05		1.2	0.6
				C.V. %		4.2	13.0

abcde Means in the same columns with different superscripts are significantly different ($P<0.05$).

1 Values have been averaged for each ration between periods.

DISCUSSION

The results indicate that ration D with a percent CP of 17.4 and an average daily intake of 3.9 kg/day produced favourable milk yields. It would thus appear that this ration had optimal nutritive status to increase and sustain high milk-yield levels. Cows fed on pure lupine showed some reluctance in consuming it; this being reflected in occasional observation of nil daily intakes particularly with decreasing levels of crude protein in the rations. This observation appears to conflict with the generally accepted concept that crude protein is the one nutritive factor that does consistently increase intake as evidenced by studies conducted by Ammerman *et al.* (1972), Mukisira and Hembry (1985).

Inference from the observations made supposes that a factor inherent in the lupine meal could be responsible for the unexpected low levels of supplemental intake with increasing ration percent CP values. There is some possibility that alkaloids result in an undesirable taste to the cows. Inclusion of maize meal in the rations tends to decrease the bitter taste with the resultant effect of increasing supplemental intake and to some extent animal performance. Considering this argument, cows supplemented with pure maize meal had the highest intake of 4.0 kg/day albeit their average milk yield was inferior to that from cows fed treatment D. This could be attributed to the lower percent CP value in the pure maize meal ration.

CONCLUSION

Data drawn from this trial show that ration D containing 75% maize and 25% lupine meals is desirable since animals on this treatment produced the highest milk yields. It also manifested fairly high intakes. Treatment rations with high lupine inclusions tended to have low intakes. This was attributed to the presence of alkaloids which impart an undesirable taste to lupine meals. It is hoped that the next stage of the study will investigate the actual alkaloid levels in the sweet lupine and to some extent establish its lupinosis effect, if any, on the liver cells of yearling steers.

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SESSION III: EXTENSIVE LIVESTOCK PRODUCTION SYSTEMS

LIVESTOCK PRODUCTION SYSTEMS IN CHOKWE, SOUTHERN MOZAMBIQUE

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Abstract

The livestock components of the mixed crop-livestock system of Chokwe District are described. This system has been undergoing changes in recent years due to an influx of people and cattle and redistribution of land in the irrigation scheme, leading to severe localised overgrazing, cattle deaths and an increased demand for animal draft power.

A pasture/soil/dry season water points survey of the area is described and the livestock carrying capacity of the various pasture types was calculated using a livestock carrying capacity model. Total livestock capacity of rangeland areas was calculated as 50340 animal units (AU) and the feed resources of the irrigation area (fallow fields and maize stover) sufficient for a further 15700 AU. Actual livestock population is 37400 AU. The problem of the area is shown to be distribution of cattle, not absolute numbers, with excessive concentrations of animals around the villages on the edge of the irrigation scheme.

The utilisation of rice straw and the introduction of appropriate forage legumes into the existing farming systems are given as ways of intensifying the production system, and these require some applied research and testing.

INTRODUCTION

Out of a total cattle population in Mozambique of 1.4 million in 1981 some 72% were found in the southern three provinces of Gaza, Inhambane and Maputo, which account for about 20% of the total area of the country. Of these cattle 86% (881,000) were in the traditional family (or communal) sector, raised on extensive grazing with some use of crop residues. The major reason for the concentration of cattle in the south is the presence of tsetse north of 22°S, a line running through the north of Gaza and Inhambane provinces.

The southern three provinces can be roughly divided into three livestock zones based on rainfall, which shows a steep gradient from the coast to the interior. The area is also bisected by three major rivers: the Limpopo (including the Elefantes and Changane rivers), the Incomati and the Maputo. Most of the family sector cattle are found along these rivers especially in:

(a) the drier interior parts (under 600 mm rainfall/year) where crop cultivation is very risky and cattle raising becomes the more important economic activity, in areas where human population densities are quite low;

(b) the area between 600 and 800 mm rainfall/year which is principally an area of mixed farming, especially on slightly heavier soils. The major activity of the family sector is crop production (principally maize and cowpeas) but cattle are kept to provide draft power, milk for family consumption, meat, economic security in bad harvest years, and as a means of investment in years of surplus; and

(c) the wetter coastal areas with their higher and more reliable rainfall (800 to 1100 mm/year), sandy soils and dense human populations. Crop production (cashew, maize, cassava and groundnuts) is very important and livestock much less so although cattle are frequently used for ploughing.

The mixed crop-livestock farming system is a very important one, involving not only a sizable portion of the national cattle herd but also a large portion of the rural population of the southern provinces.

The district of Chokwe lies in the mixed farming zone on the southern side of the Limpopo river. There has been recent immigration of cattle and people into this relatively safe district from surrounding areas affected by the war, and concentration of a previously more scattered population into villages on the edge of a large irrigation scheme. This has caused many cattle to die of hunger in the dry season. The pasture and animal feed potentials of the district are large, and there has been a big increase in demand for draft oxen for use in the irrigation scheme. The need for intensification of livestock production is clear. Because of this situation a study was carried out (Timberlake *et al*, 1986) into the carrying capacity of the pastures and the distribution of dry season watering points in the area. This would assist in a more rational use of existing feed resources and provide a basis for land use planning for livestock production.

This paper is in two parts. The first part describes the recent survey mentioned above, while the second part discusses these results, and results from other surveys in the area, from a farming systems perspective and gives some suggestions as to future lines of investigation.

STUDY AREA

Chokwe District in Gaza Province, in which the study area of 1830 km^2 is located, is primarily an agricultural district situated on the south side of the Limpopo river some 100 km from its mouth. It is characterised by a low and variable rainfall (averaging 623 mm/year, mostly falling from November to March) and high evapotranspiration (1413 mm/year) leading to high agricultural risk in dryland farming areas. A large irrigation scheme of approximately 37,000 ha, mostly for rice, maize and vegetables, is the major feature of the district. Since 1983 some 13,000 families have been granted plots of 0.5 to 1 ha in 9,000 ha of the scheme. Surrounding this are dryland grazing areas, some of which are cultivated in the form of small family plots. Maize and cowpeas are the major crops, but cassava, groundnut and sweet potato are also grown. Cattle are an important component of the farming systems of the region, principally providing draft power. Goats are common but not numerous.

The area is flat to gently undulating and consists basically of marine deposits overlain in places by more recent colluvial and alluvial deposits. Soils close to the river are sandy but fertile, while the rest are sandy loam in texture. These latter areas are dissected by large shallow depressions of clay soils which form water-courses for a few weeks of the year. In the southeast of the study area, rising above the rest, are interior dunes of reddish sands.

METHODOLOGY

The study was in three parts: a soil survey, a pastures/vegetation survey and a dry season water points survey.

Soil Survey

The soil survey was at a reconnaissance level. A photo-interpretation map was prepared based on aerial photographs at a scale of 1:40,000 flown in 1973. On this map the main physiographic/soil units were distinguished. Fieldwork consisted of 89 soil auger observations to a depth of 1.2 m in locations thought to be representative of the various physiographic units. The following characteristics were recorded: physiography, slope, drainage class, actual land use, soil texture, soil colour and mottling, soil consistency, presence of calcium carbonate, salinity and depth of groundwater table. Some 76 soil samples were also taken for laboratory analysis including pH and mineral content. On the basis of the fieldwork the preliminary photo-interpretation map was adjusted and a final soil map prepared at a scale of 1:75,000.

Pasture/Vegetation Survey

The pasture/vegetation survey was done at the same reconnaissance level. Using the same aerial photographs, 100 observation points were chosen, representative of the varying physiographic and vegetation units distinguished. At each observation point the tree, shrub and grass species present were noted with an indication of their cover/abundance. The observation points covered an average of 0.5 ha each and were not sited in heavily disturbed areas or inside the irrigation scheme.

A matrix was later made of observation points along one axis and species along the other. This matrix was rearranged repeatedly on a micro-computer so that species which tend to be associated, and observations of similar species composition, were placed together. After various rearrangements clear groupings of observation points emerge and these form the basis of the vegetation units. The pasture/vegetation map was made using a modified version of the physiographic/soil map.

From the map the areas of each pasture/vegetation type were determined. Potential livestock carrying capacities of each type were determined using the potential pasture productivity and livestock carrying capacity model of Timberlake and Reddy (1986). The assumptions used are given in Tables 1 and 2

Table 1. Livestock carrying capacity calculations for vegetation units in Chokwe[1/].

Vegetation unit	Estimated potential primary productivity (t DM/ha/year)[2/]	tree and shrub cover (%)	ha/head[3/]
Broad-leaved woodland	6.0	10	1.0
Broad-leaved woodland			
- light bush	2.2	20	3.6
- heavy bush	2.2	40	7.1
Acacia savanna			
- light bush	2.5	20	3.2
- heavy bush	2.5	40	6.3
- very heavy bush	2.5	50	8.8
Open grassland			
- Themeda	3.0	0	1.8
- Dactyloctenium	2.0	0	2.7
- wet area	6.0	0	0.9

1/ Using the model of Timberlake and Reddy (1986) and assuming 50% use factor and an animal feed intake of 2740 kg DM/head/year for a 350-kg animal with 100 gm/day LWG.

2/ 75% probability value.

3/ 1 head = 1 adult 350-kg animal.

Source: Timberlake *et al.* (1986).

Water Point Survey

In determining dry season water points all points where water appeared to accumulate were noted on aerial photographs. Local information was used in locating those points (less than half) which still had water during September-October (dry season), and this proved quite reliable. A questionnaire was filled in at each point concerning the presence of water, type, present condition, age, size and depth, where the cattle came from which use it, overgrazing/erosion, and whether it sometimes dries up. The system of canals inside and on the edge of the irrigation scheme were not included as access by cattle is possible along most of their length.

Table 2. Areas of vegetation types and livestock carrying capacities in Chokwe.

Vegetation/land type	Area (km^2)	Carrying capacity (ha/head)	Total Livestock capacity ('000 head)
Riverine woodland	61.0	3.0[a]	2.03
Broad-leaved woodland	226.9	6.0	3.78
Acacia savanna	849.9[b]	5.0	15.10
Open grassland	294.3	1.0	29.43
SUB TOTAL	1423.1		50.34
Irrigation scheme	370.7	-	15.70[c]
Plantation forest	12.4	-	-
Open water	6.8	-	-
Urban areas	8.3	-	-
TOTAL	1830.3		66.04

a. Assuming that only half of the area can be grazed; rest is cultivated.

b. Assuming 0.5 ha cultivated in this unit per family and 19,000 families, leaving 754.9 km^2 available for livestock.

c. Uncultivated and saline areas, and maize stover from Table 3.

Source: Timberlake *et al.* (1986).

RESULTS

Soil Survey

The description of the soil units is based partly on data collected during the study, but also on the descriptions of Touber and Noort (1985) who carried out a detailed survey of the irrigation scheme. The 14 soil units determined can be divided into four major groups:

- soils of the interior dunes
- soils of the marine Pleistocene sediments on elevated areas
- soils of the marine Pleistocene sediments in the broad depressions
- soils of the recent fluvial sediments of the Limpopo river.

In general, the soils are quite fertile (except those of the interior dunes), but the soils from marine sediments in the broad depressions often show rooting limitations due to the heavy clay and to periodic inundation. A good correlation was seen in the field between soil type and pasture type, although the length of inundation was also an important factor.

Pastures/Vegetation

Four major pasture/vegetation units were determined and described:

1. **Open Riverine Woodland.** Characterised by large spreading trees of *Ficus sycamorus*, *Trichilia emetica*, *Acacia albida* and *Sclerocarya caffra*. Grass cover is mostly composed of *Urochloa mosambicensis*, *Panicum maximum* and *Cynodon dactylon*, with *Setaria incrassata* and *Ishaemum afrum* on the black clay soils. Most of the area is of light alluvial, well-drained soils, nearly all used for traditional cultivation.

2. **Broad-leaved Woodland.** A woodland or bushland type with *Terminalia sericea*, *Sclerocarya caffra*, *Albizzia versicolor*, *Strychnos spinosa*, *S. madagascariensis*, *Tabernaemontana elegans* and occasionally *Hyphaene natalensis*. Grass cover is mostly of *Panicum maximum*, *Cynodon dactylon* and *Digitaria eriantha*. Soils are sandy, and much is used for traditional cultivation. Burning is frequent.

3. **Acacia Savanna or Woodland.** A woodland to tree/bush savanna with *Acacia welwitschii*, *Euclea undulata*, *A. senegal*, *A. nilotica*, *Omocarpum trichocarpum* and *Albizzia petersiana*. *A. xanthophloea* is found in wetter areas. In the far northwest of the study area mopane (*Colophosperum mopane*) woodland occurs. Grass cover varies from *Dactyloctenium geminatum* and *Sporobolus nitens* to *Themeda triandra* depending on soil type. *Termitaria* sp. are often present. Soils are mostly sandy loams and cultivation is limited to the edges of the broad depressions.

4. **Open Grassland.** An open grassland with very few trees or shrubs of *Acacia xanthophloea* and *A. nilotica*. Grass cover is of *Echinochloa colona*, *Eriochloa stapfiana*, *Panicum coloratum*, *Eragrostis* cf. *inamoena* and *Cyperus* spp. *Termitaria* sp. are generally absent. These areas are flooded for varying lengths of time; soils are heavy black clays. There is no cultivation and the grasslands are only used for grazing.

Results from the livestock carrying capacity calculations are shown in Table 1, and total livestock carrying capacities of the different pasture/vegetation types are shown in Table 2. Gross estimates were also made of feed resources inside the irrigation scheme and are shown in Table 3.

Water Points

Excluding irrigation canals and the Limpopo river, 70 water points were found with water in the dry season. An additional 90 points which appear to contain water in the early dry season were noted from aerial photographs. The 70 points with water were divided into nine types: lakes, rivers, irrigation canals, small dams, small reservoirs, road excavations, boreholes, wells and natural depressions. Twenty major water points were noted and it was seen that the irrigation system, directly or indirectly (through raised groundwater levels filling excavations), is by far the most important source of water. There are 40 small reservoirs specifically made for use by cattle, but only 14 now contain water through the dry season due to silting up and lack of maintenance. The Mazimuchopes river dries up to a few pools in the dry season.

Table 3. Estimated feed resources inside the Chokwe irrigation area.

	Area (ha)	DM production/ ha/year	Feed available ('000 tons DM/yr)	Use factor	Cattle[a] supporting capacity ('000 head)
Uncultivated areas	5000	25000	12.5	0.7	3.2
Saline areas	2000	1000	2	0.3	0.2
Maize residue	7000	6000[b]	42	0.8	12.3[c]
Rice straw	n/a	3700[d]	43[e]	0.8	11.5[f]
Total	-	-	99.5	-	27.2

a. Assuming 2740 kg DM/year animal intake for a 350 kg animal.

b. ILACO (1981, p.476). Actual recorded grain yields are 1.8 t/ha with 13% moisture in the cool season, and 0.6 t/ha in the hot season (Woodhouse *et al.*, 1986).

c. Assuming 6% protein.

d. Assuming 1:1 ratio of grain:rice. State farm production data averages 4 t/ha grain if a 50:50 ratio of the two varieties grown is used, however var. C4-63 has less vegetative growth (Woodhouse *et al.*, 1986).

e. Assuming 1:1 grain:rice ratio and commercialised rice production data.

f. Assuming full urea treatment and 3 t DM/year animal intake. In practice urea-treated rice straw would be used as a supplement.

Source: Timberlake *et al.* (1986).

A notable feature of the distribution of water points is that most of them are situated on or near the edge of the irrigation scheme. Between the irrigation scheme and the Mazimuchopes rivers some 13 to 30 km distant, there is virtually no source of water, so cattle are overgrazing some areas and underutilising other good pasture areas 8 to 15 km away.

DISCUSSION

Importance of Draft Power and Other Livestook Practices

The number and class of cattle in the area is reliably recorded every year on the basis of the dip tanks. It is probably an underestimate due to immigration of unregistered cattle and the possibility that owners with one or two head do not bring their animals to be dipped. Table 4 gives the numbers and classes of animals and shows the high percentage of oxen in the family sector herds compared to commercial herds. These cattle, however, are not evenly distributed, and great concentrations are found associated with villages bordering the northwest edge of the irrigation scheme. Average herd sizes have been calculated from livestock census data for different localities. They are very variable, ranging from 4.4 to 38.7 head/family, with a mean of 9 head (Vet. Fac., 1986).

Table 4. Cattle population, Chokwe district, 1986.

	Oxen		Cows		Calves <1 yr		Total	
Sector	No.	% of sector	No.	% of sector	No.	% of sector	No.	% of total
Family	9179	18.9	16316	33.5	7362	15.1	48650	84.5
Private	156	1.8	3081	35.7	2842	32.9	8636	15.0
State	-	-	158	49.7	50	15.7	318	0.5
TOTAL	9335		19555		10254		57604	

A recent study by Rocha (report in preparation) on traditional livestock practices carried out in three villages in the southwest of the study area and away from any major influence of the irrigation scheme, shows that only 2.1% of livestock owners interviewed did not have oxen, although 100% had a plough. The strong positive relationship between number of draught animals and area cultivated noted in this study is shown in Table 5. A Veterinary Faculty study (1986) into livestock practices in Chokwe District, also carried out by questionnaire, found that 27% of family sector animals were used for ploughing and/or transport, of which only 76% were oxen. The other 24% were principally cows but also included bulls and steers. Within the irrigation scheme a study into agronomic practices of families with small plots (Woodhouse *et al.*, 1986) showed the great importance of animal draught power there, which varied with the cropping system and averaged 83% (Table 6).

Subsistence production of milk is widespread, although previously not fully recognised. Rocha's study found that 10.6% of livestock owners in Mazimuchopes do not have cows, but of those that do 93% milk in the wet season. Data on yields are still not available, but it can be assumed that yields are around 1 to 1.5 litres/day/producing cow. Milking is much less practiced in the dry season; questioned in July (dry season), only 26.5% of cattle owners said they milked their animals (Vet. Fac., 1986), but it is not clear if they were speaking generally or referring to that month in particular.

Table 5. Relationship between draught animal ownership and area cultivated around Mazimuchopes.

Number of draft animals per family	Mean area cultivated (ha)
1-2	1.1
3-5	1.9
6-9	3.6
9+	2.6

Source: Rocha (unpublished data).

Table 6. Ownership and importance of oxen in two major cropping systems in the Chokwe irrigation scheme.

		Maize	Rice	Mean
Plots ploughed with oxen (%)		92	65	83
Ownership of:				
oxen	rainfed plot (%)			
+	+	34	25	31
+	-	24	9	19
-	+	16	10	14
-	-	25	55	35

Source: Woodhouse *et al.* (1986).

Supplementary feeding appears to be an important practice of traditional livestock owners. In the Mazimuchopes study Rocha found that 32% of livestock owners gave maize stover and/or failed maize crops, 9% gave cut grass in addition to maize stover, and 2% make hay for dry season use. In the Chokwe irrigation scheme in 1987 farmers were selling maize stover at 1000 meticais (around 25% of the minimum monthly agricultural wage) per cart load (approximately 200-300 kg) at the farm, i.e. transport is not included. This however was at a time when grazing was poor because of a mid-season dry spell.

A measure of the sophistication of a farming system is its use of salaried labour. It is therefore interesting to note that 32% of livestock owners employ salaried labour for herding (Rocha, unpublished data), although the influence of receipts from migrant labour in South Africa probably plays an important role.

Carrying Capacity of Natural Pastures and Grazing Limitations

The calculated carrying capacities given in Table 1 show the good grazing potentials of the area. The importance of the open grassy depressions is very clear, although for some months of the year they are inundated and not utilised. This however is in the wet season when sufficient grazing is available in the *Acacia* savanna pasture type. Actual primary production data from these areas are not available and it is important to collect some.

If grazing were evenly distributed the livestock carrying capacity of the natural pastures in the study area is 50,340 adult head, perhaps 64,000 head with the existing herd structure. The number of animals in the study area (which does not cover the whole of Chokwe District) is estimated at around 47,500 head, giving a theoretical possibility of increase of 16,500 head. The problem of course is that grazing is not consistent with the distribution of grazing resources for three major reasons:

1. owners are afraid to graze the relatively unpopulated areas away from the irrigation scheme because of cattle thieving and the civil war situation;

2. most of the cattle are associated with the villages along the edge of the irrigation scheme and kraaled there at night; and

3. the great lack of dry season water points away from the irrigation scheme and the resulting long distances from grazing to water.

Overgrazing around the major villages is severe and some hundreds of animals die from hunger near water points in the late dry season. The two most practical ways of overcoming the problem are (a) to intensify livestock production with the use of forages or treatment of crop residues, or (b) provide water in the dry season in presently underutilized areas where this, rather than security or distance to the night kraal, is the limiting factor. The pasture study has made recommendations on some suitable locations for water points, which make use of runoff water that can be captured and stored in a small (approximately 100 x 50 x 3 m) reservoir. These reservoirs, many of which were constructed in the past but have not been maintained, only require re-excavation every two or three years and otherwise have no running costs.

Bush encroachment is found in the *Acacia* savanna and broad-leaved woodland vegetation types, particularly the former. Here it seems to be more acute in areas that are or were commercial ranches. However, some of the species causing bush encroachment in the *Acacia* savanna type are suitable for browsing.

Feed Resources in the Irrigation Scheme

The irrigation scheme is the centre of nearly all agricultural activity in the district, and thus produces large quantities of crop residues, principally rice straw and maize stover. There are, in addition, large areas of fallowland; estimates are as high as 13,000 ha, but 5,000 ha would seem a safer figure, and perhaps a further 2,000 ha of abandoned saline areas. In theory cattle are not allowed to enter the irrigation scheme except working animals because of the damage they cause to the canal banks and crops they might eat. But this is not enforced and large numbers of cattle can be seen inside feeding on maize stover at the end of the season, in fallow fields, and grazing on weeds and regrowth in the rice fields after harvest. It is rather difficult to quantify these feed resources, but estimates were made (Table 3). The theoretical carrying capacity was calculated assuming that the animals would be living entirely off these feed resources, which is far from the real situation as they are not available year round. However, their importance can be seen, not only at present when fallow areas and much of the maize stover is utilised, but also the potentials of the large quantities of rice straw which are now normally burnt. This requires an applied research programme into the best and most cost-effective methods of treatment to increase its acceptability and feed value at the level of small-scale livestock producers.

Cereals are not the only crops grown in the irrigation scheme. Cowpea (*Vigna unguiculata*), common bean (*Phaseolus vulgaris*), *Lablab purpureus* and pigeon pea (*Cajanus cajan*) are frequently found grown with maize. These increase the protein value of crop residues when grazed together, but foliage productivity data are not available. *Lablab* in particular shows promise as a dual-purpose crop-grain for human consumption and foliage for cattle. It is normally planted with maize under dryland conditions at the end of the main rains (March/April), but the plants are small. If planted one month earlier foliage production is much higher (Heemskerk, pers. com.). Some trials were carried out on *Melilotus alba* under irrigation as a cool-season crop after rice (Woodhouse *et al.*, 1986). Forage dry-matter yields averaged 3.6 t/ha. Lucerne (*Medicago sativa*) has been grown commercially inside the scheme.

Outside of the irrigation scheme *Cajanus*, *Lablab* and *Leucaena* spp. would appear, from personal observation, to offer the best prospects as forages or dual-purpose crops that could be utilised as animal fodder by traditional farmers.

CONCLUSIONS AND FUTURE LINES FOR INVESTIGATION

Chokwe District is undergoing a challenge as regards livestock production. It is an area with a strong livestock tradition in which the provision of draft power is of the greatest importance, and an area with a large agricultural potential due to fertile soils and a large irrigation scheme. The challenge is due to an unstable and rapidly changing situation caused by various factors:

(a) the civil war situation, resulting in a large influx of cattle and people from less-secure surrounding areas and a fear of grazing animals far from the villages;

(b) the recent concentration of villages, and therefore cattle, along the periphery of the irrigation scheme leading to localised but severe overgrazing;

(c) the impending return of much of the migrant labour force from South Africa which provides much of the cash and goods to the family economies of the area;

(d) land use conflicts between livestock and dryland arable farming concentrated around the villages;

(e) the conflict between livestock and the management of the irrigation scheme which severely limits grazing of cattle within its limits (before a major dry-season grazing area) due to damage caused to canals and crops;

(f) the insufficient quantity and quality of feed during the dry season for the draught animals which carry out an important part of the agricultural work inside and outside the irrigation scheme; and

(g) the poor distribution of dry-season water points away from the irrigation scheme which limits accessibility to pastures because of excessive distances from grazing to water points and finally to the night kraal.

With increasing land use pressure there is now a need for a more rational use of available resources (grazing, water, crop residues, etc.), and the need for intensification of traditional livestock production is clear. In the foreseeable future most agriculture will continue to be carried out by draft animals and will be in or close to the irrigation scheme. These animals need good feeding to maintain their strength, and the scheme will have a big role in providing their feed. Forages grown within the existing smallholder farming systems and better utilisation of crop residues are the main ways to achieve this.

Recent studies discussed in this paper give a general idea of traditional livestock practices in the area, the principal problems and the feed resources available. Some future lines for investigation regarding animal feeding can be drawn from this:

(a) Two or three detailed village-level studies need to be carried out in environmentally different zones in the region to determine and quantify livestock practices and constraints to production. These should include size and composition of individual herds, grazing practices, use of crop residues and quantification of weight losses (especially cows and oxen). This will ensure that future interventions by the extension service are appropriate and have a good impact.

(b) The relative importance and problems of goats which should be better adapted to shortage of grass and water.

(c) Determination of the relationship between cultivation in the irrigated areas and cultivation under dryland conditions, as most smallholders in the irrigation scheme also have a plot outside and animal draught power is used in both.

(d) Determination of pasture and animal productivity from both natural pastures and crop residues and the determination of carrying capacities on a more detailed level.

(e) Determination and testing of appropriate methods of improving acceptability of rice straw, i.e. urea treatment or treatment with molasses. This testing should preferably be done through farmer-managed trials.

(f) Suitable methods of storing maize stover and rice straw for use later on in the season without losses in nutritive value.

(g) Intercropping of maize with *Lablab*, cowpeas and other suitable dual-purpose legumes with a view to improving the protein levels of crop residues. Some of the leafier legume varieties available from ICRISAT, IITA and other institutions presently available in the country can be used.

(h) The use of *Cajanus* as forage including selection of leafier varieties, its place in the cropping pattern and management techniques.

(i) The use of *Leucaena* as a forage reserve in dryland areas and around the village. Any limitations to its use (e.g. productive losses due to mimosine) should be investigated also.

(j) Economics and production effects of supplementation with urea/molasses and phosphate blocks.

The area of Chokwe is somewhat unique due to the influence of the irrigation scheme, but many of the traditional agricultural practices there are found over a large and important area of southern Mozambique. The impact of livestock or forage-related research, and good extension packages, on this farming system would be large. It would also greatly improve crop production in the area through a more efficient use of animal draught power, thus the rural family economies would become more stable.

The problems are now reasonably clear but still require some further quantification. Solutions have been suggested, but work has not really commenced on their viability. Given the limited resources in research a cooperative approach is required, with soil surveyors, land use planners, pasture agronomists, crop agronomists and animal production specialists working in coordination.

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PRODUCTION OF THE MALAGASY EXTENSIVE LIVESTOCK

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INTRODUCTION

Ruminant production is far more important than that of non-ruminant in the Malagasy state. The livestock population is distributed as follows (MPAEF, 1986):

Cattle	10,485,000
Sheep and goats	1,829,000
Pigs	1,350,000

Of the 12,341,000 ruminants, more than 90% are raised in an extensive system. This is predominant in the western and southern parts of the island, where land is still available for grazing, as the human population density is rather low between six to eight persons/km^2.

The Malagasy cattle owner is also a rice producer. He lives in a sedentary system and his priorities for keeping animals are obviously different from those in developed countries. So productivity may be understood as the high number of zebu cattle which reflect his wealth and the ability to sell and/or slaughter at the occasion of traditional festivals. Productivity also means the working capacities of the zebu herds for draught, their manure and milk yield. For the national economy on the other hand, livestock productivity means the meat for domestic consumption and export.

This paper analyses the different patterns of zebu cattle productivity in order to make some suggestions for research priorities and productivity improvements.

METHODOLOGY

Data presented here were collected from two sources: the first was from Ministry surveys (MDRRA, 1979; MPAEF, 1986) and the second from the Miadana Research Station.

Ministry Surveys

Two surveys were carried out during the last ten years. The first was from November 1978 to February 1979; the second from June to December 1984. The purpose of these studies was to acquire some data about the main features of the livestock population. The surveys used the stratified sampling procedure. It is clear that the collected information was not complete and accurate. But by such periodic appraisal it is possible to get the major trends of the national herd.

Experimental Station

Miadana Station (15^{o} 36'S; 46^{o} 38'E) is the only research station covering the western and southern zones. It is located 60 km from Mahajanga, and the mean annual rainfall is 1,450 mm. Some data on the zebu weight gains and reproduction performances of improved management systems were collected from this station.

RESULTS

The extensive livestock system is well spread all over Madagascar, but the western and southern provinces are the most representative of the system. These two provinces cover 318,000 km^2, nearly 55% of the island's total area, and 61% of the national zebu cattle herd is raised in these two provinces. The climate varies from subhumid in the northern part to sub-arid in the southern region. The rains fall between November and April, and the dry season may last six to nine months of the year.

Feed Resources

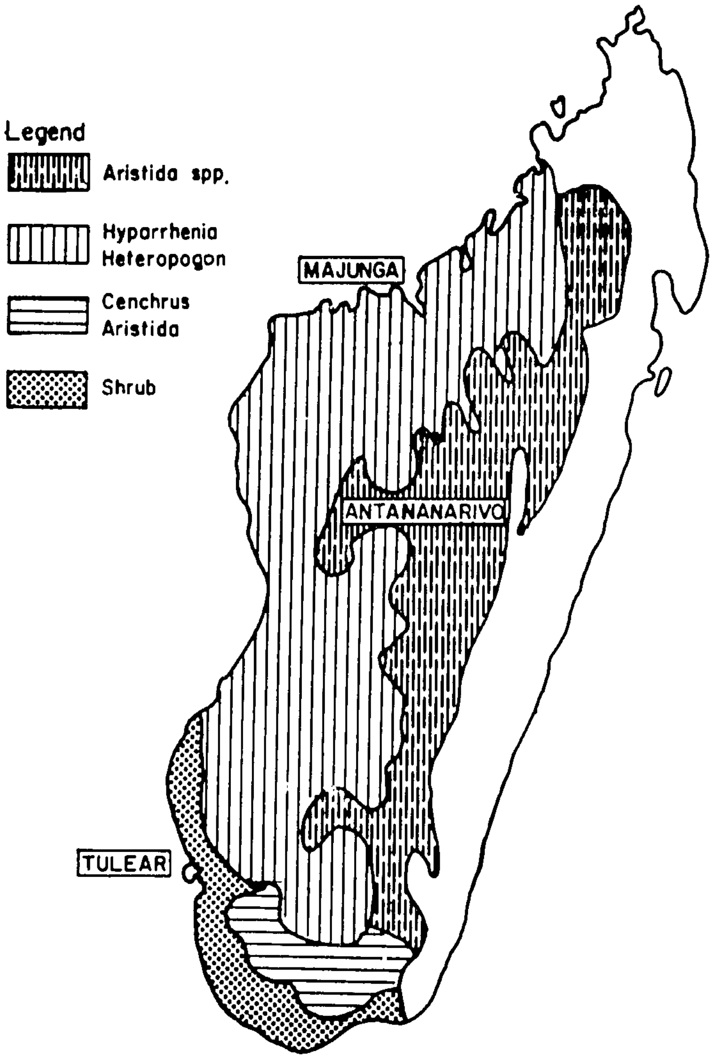
The most important feed resources are natural pastures, crop residues and to a limited extent, improved pastures. The grazing lands are dominated by four grass species: *Heteropogon contortus, Hyparrhenia rufa, Chrysopogon serulatus* and *Aristida rufescens* (Figure 1) (Cabanys and Razafindrastsita, 1971; Granier and Bigot, 1972; Morat, 1972; Suttie, 1974a). In the south the grasses are replaced by shrubs.

Generally the edible dry matter available during the rainy season is sufficient as the stock is not able to eat all the grass produced. After the rainy season there is a rapid change of nutritive value in the grassland. Crude protein content particularly may be as low as 2% in September (Figure 2). The management of this natural grassland is not controlled, except in the Androy region (south), where there is a traditional deferred grazing area ranging from 2 to 200 ha, which is only grazed in the dry season. This deferred grazing land is called Adily (Ratsimba-Rajohn and Razafindratsita, 1977). It belongs to a family or a local community, and their livestock are the only ones authorised to graze on it.

Several pasture improvement tests were performed (Borget, 1971; Suttie and Hablutzel, 1975; Rasambainarivo et *al.*, 1980), particularly with leguminous species. The best adapted are *Stylosanthes guianensis, Stylosanthes humilis, Stylosanthes hamata* and *Macroptilium atropurpureum* (siratro), but they failed in practical extension due to socio-economic reasons.

In the south, thorny cactus is a traditional multipurpose plant. It is firstly used as fence around villages and fields. It is also cut, burnt and distributed to livestock in the dry season. The mature fruit is appreciated by humans. Some thornless cacti were tested (Suttie and Matzernmiller, personal communication); they give higher yield in terms of fodder although their management is more difficult, and they cannot be used as fences, so their extension is very limited.

Figure 1. Grazing lands in western and southern Madagascar.



Since rice is planted all over the island, rice straw is therefore the most common crop residue. It is usually left in the field after threshing and consumed by zebu cattle without any treatment. Weeds growing in the rice fields are also grazed after harvest. Other crop residues are maize and sorghum stovers, cassava, sweet potatoes, vines and groundnut haulms. A survey carried out in 1977 indicated that 70% of the cattle owners utilise crop residues for animal feeding.

Agro-industrial by-products are not available for extensive livestock due to their high cost and transport problems.

Herd Structure

The Malagasy zebu is the major breed constituting the extensive cattle population. Herd composition (Table 1) indicates that females are more numerous than males and the bull:cow ratio is about 1:18. No culling of infertile females is practiced because legally they are not to be slaughtered. More than half of the stock are four years old and over, and about 11% are more than ten years old. In this old group the majority are castrated males.

Figure 2. Crude protein contents of natural pasture in western and southern Madagascar provinces.

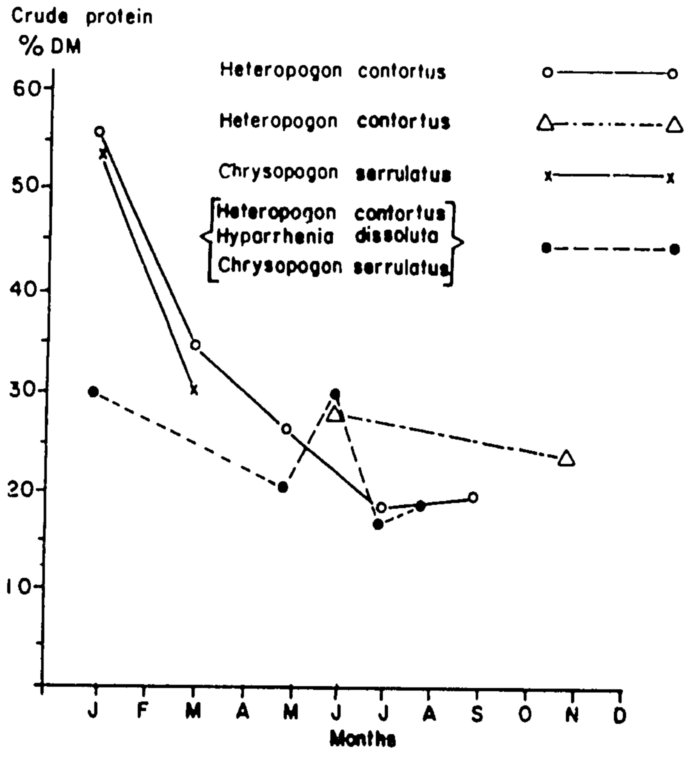


Table 1. Composition of household herd in Faritany Mohajanga in 1984.

Age (years)	Males	Females	Total
Less than 1	8.4	9.2	17.6
1 - 3	12.0	14.0	26.0
4 - 9	15.3*	30.0	45.3
10 and over	3.6*	7.4	11.0
Total	39.4	60.6	100.0

* 11.8% are castrated males.
Source: Sarniguet and Hartier (1986).

Reproduction Performances

Reproduction performance data are presented in Table 2. The data were collected all over Mahananga Province. The data for Miadana Station are averages for a ten-year period. The calving rate is quite variable in the traditional management system, ranging from 44.7% to 68.6%. In the "Miadana" conditions, the mean rate is 67.3% (Rakotobe-Ralako, 1987).

Table 2. Extensive reproduction performance.

	Regional Mahajanga survey	Miadana station
Calving rates (%)	58	67 ±8
Age at first calving (months)	60	54
Calving interval (days)	420	377

In the extensive situation the age at first calving is longer. The calving interval is also longer. These data are in agreement with the report by Rakotobe-Ralako, (personal communication) who reported that in well-managed herds of zebu cattle age at first calving may be as short as 28 months compared to a range of 48 to 68 months under extensive management. The calving interval was extended in extensive management systems.

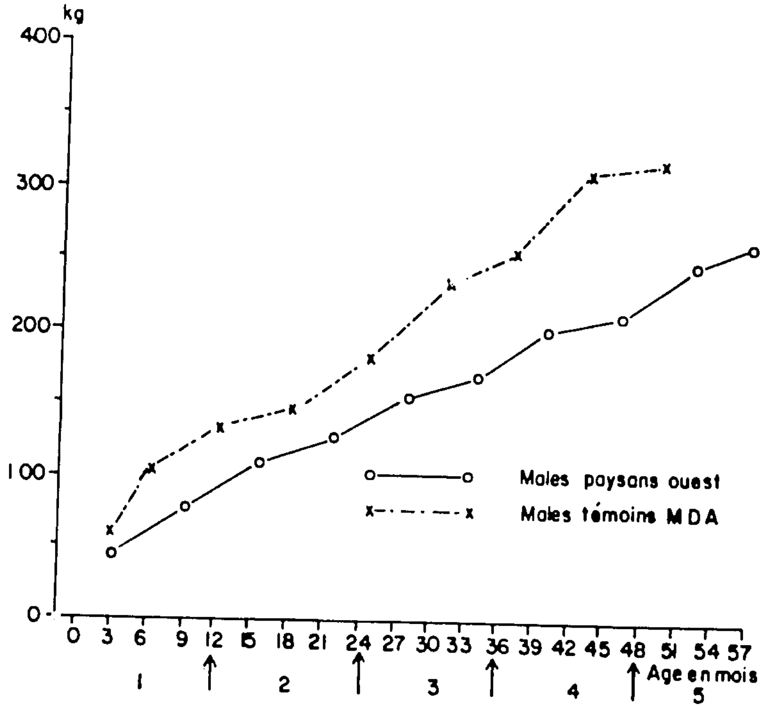
Mortality varies widely depending on the age. The most important mortality is that of calves less than one year old; 21% of these calves die in the extensive system conditions. The mortality rate decreases as the zebu get older, and the overall mortality is estimated to stabilise at 7.5%. All these reproduction data will vary depending on seasonal availability of nutrition.

Liveweight Changes

The general pattern of Malagasy zebu growth in extensive system is presented in Figure 3 which compares smallscale owner and research station cattle. As expected, the rate of growth of the better managed station cattle is higher than that of the extensively managed. Even at the end of 48 months after birth the station-managed cattle are heavier by about 50-75 kg (Ratovonirina, 1983).

Considering the growth rates within the first 36 months, it is evident that the worst period lies between the 6th and 18th month of age. This period coincides with weaning, a period when daily weight gain decreases from 458 g to only 90 g/day.

Figure 3. Weights of Malagasy Zebu in extensive and station conditions.



Source: Ratovonirina (1983).

Comparative livestock productivity studies have shown that stocking natural grasslands at one animal/ha induces a weight loss whereas on legume reinforced planted pastures stocked at the rate of three animals/ha the animals were able to gain at 0.3 kg/day. These data show the potential for improvement of the extensive grazing land resources in Madagascar (Rasambainarivo *et al.*, 1985).

Slaughter Performances

Nearly all the cattle slaughtered are zebu coming from extensive systems. These slaughters represent a national carcass consumption of 13.1 kg/ha/annum. This figure is doubtful as there are a lot of cattle slaughtered but not recorded. The mean carcass weight of Malagasy zebu cattle is 172 kg. The majority of slaughtered zebu are more than eight years old. Nevertheless, in a better environment the zebu carcass may weigh 200 kg (Gilibert, 1971).

Milk Production

Milk production is low in extensive systems. Data were collected in the suburbs of Mahajanga. The mean individual cow production is estimated at 350 litres for a 200-day lactation (Planchenault, 1986). In the deep south of the Androy region, milk is also produced and traditionally processed, but milk production records are not available.

CONCLUSION

From the data reviewed, it is evident that the major factor limiting production of the zebu cattle in Madagascar under extensive production system is inadequate nutrition which leads to poor reproduction and weight gain performance. The zebu cattle may not be expressing their full potential as a result of the nutrition problem under these conditions. Notwithstanding the socio-economic constraints to improving livestock production, an improvement of the feed resource would invariably increase the reproduction performance of cows and reduce calf mortality.

More accurate information about the different management systems is required, and more comprehensive surveys must be carried out. Additional research information should be gathered about the status of bovines on-farm. And all of these data have to be used with a computer model for a production system simulation. As beef production is a rather complex enterprise, improvement can only be successful if it is carried out by inter-disciplinary teams on national and regional level.

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THE PREDICTION OF RANGELAND PRODUCTION FROM RAINFALL DATA IN ARID AND SEMI-ARID EASTERN AFRICA

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Abstract

Relationships between rainfall and peak biomass were analyzed for eight sites in arid and semi-arid areas in Kenya and northern Tanzania. These sites received average annual rainfall ranging from 200-600 mm falling mostly in a bimodal pattern. Regression equations of seasonal biomass were significant for all sites explaining 56 to 99% of the variation. Predicted seasonal biomass was 1200-2000 kg DM ha^{-1} at 300 mm and 2100-3900 kg DM at 500 mm of rainfall. Differences between sites were due to species composition, soil type and herbaceous cover density. These data sets were compared to similar regressions for west and southern Africa. It was concluded that productivity per unit of rainfall in East Africa was higher than these other regions because of bimodal rainfall and higher soil fertility.

INTRODUCTION

In recent years relationships between seasonal rainfall and end of season herbaceous biomass have been published for several regions in Africa. For the Sahelo-Sudanian region data were compiled by Le Houerou and Hoste (1977) followed by studies in Mali by Penning de Vries and Djiteye (1982). For Eastern and southern Africa regressions between annual rainfall and herbaceous biomass were developed by Deshmuck (1984) which showed that per unit of rainfall biomass production in this region was twice as high as in West Africa. However, similar regressions for southern Africa given by Rutherford (1978) indicate that productivity of rangelands in Zimbabwe and Botswana is much lower than in East Africa.

The purpose of this paper is to focus on the productivity of rangelands in arid and semi-arid Eastern Africa and indicate which factors are responsible for the substantial higher levels of productivity in this region as compared to southern and western Africa.

METHODS AND DATA SOURCES

Relationships between rainfall and peak biomass were analysed for sites in Kenya and Tanzania. All sites were located in areas with arid or semi-arid climates having seasonal rainfall ranging from 100 to 600 mm falling mostly in a bimodal pattern due to their location around the equator (Tables 1 and 2).

Raw data were obtained for three sites in semi-arid Kenya: (1) Kiboko Research Station (Too, 1985); (2) Athi plains (Potter, 1985); and (3) Tsavo National Park (van Wijngaarden, 1985). These three sites are all located within the pastoral land use zone (cf. Jaetzold and Schmidt, 1983). Additional data sets were used as supplementary sources: Amboseli (Western and Grimsdell, 1979), Serengeti (Sinclair, 1979; Braun, 1973).

Table 1. Relationships between rainfall and herbaceous standing above-ground biomass in bimodal rainfall areas in Kenya and Tanzania.

Area	Average annual rainfall b/	Principal genera	100	300	500
			kg DM ha^{-1}		
Amboseli (IV) b/	300- 550	*Sporobolus-Pennisetum*	10	760	1510
Kiboko (V)	450- 900	*Digitaria-Chloris*	670	1490	2300
Serengeti (IV)	600-1100	*Sporobolus*	-a/	1190	2150
Tsavo (VI)	300- 550	*Chloris-Chysopogon*	420	2020	3620
Serengeti (IV)	600-1100	*Themeda*	-a/	1570	3700
Serengeti (IV)	600-1100	*Themeda* in woodlands	470	1790	3100
Athi (V)	450- 900	*Themeda*	10	1370	3860
Serengeti (IV)	600-1100	*Andropogon*	-a/	1520	3230

a/ The data did not cover rainfall below 200-250 mm.
b/ IV-VI Moisture availability zones and the annual rainfall according to Braun (in Sombroek et al, 1982).

Table 2. Regression equations for seasonal rainfall on standing biomass in East Africa.

Area	Equation		Reference
Amboseli	Y= -367+3.8X	(N= 6; R^2 = 0.99)	Western and Grimsdell (1979)
Kiboko	Y= +262+4.41	(N= 38; R^2 = 0.78)	Too (1985)
Serengeti	Y= 262+4.8X	(N= 7; R^2 = 0.93)	Braun (1973)
Tsavo	Y= 380+8.0X	(N= 89; R^2 = 0.65)	van Wijngaarden (1985)
Serengeti	Y= -1644+10.7X	(N= 12; R^2 = 0.62)	Braun (1973)
Serengeti	Y= -185+6.6X	(N= 24; R^2 = 0.90)	Sinclair (1979)
Athi	Y= -251+1.2X+0.01X2	(N= 24; R^2 = 0.95)	Potter (1985)
Serengeti	Y= -1052+8.6X	(N= 10; R^2 = 0.56)	Braun (1973)

Y = Biomass in kg DM ha^{-1}; X = rainfall in mm.

In Kiboko a clipping trial was carried out from February 1982 to December 1984 in four neighbouring vegetation types. The plant cover consisted mainly of perennial grasses with a medium to light cover (10-30%) of *Acacia* and *Commiphora* shrubs and low trees. Seven different cutting regimes were applied together with two defoliation intensities (cutting at 5 and 12.5 cm height). Within each vegetation type the 14 treatment combinations were repeated on land that was burned prior to the start of the trial and also on unburned land. Only data from the high intensity defoliation treatments were used assuming that harvesting at 5 cm height best represented available biomass. As the effect on herbaceous biomass growth of burning and vegetation type or their interactions were not significant (Too, 1985), these were combined in the re-analysis, giving 38 pairs of data of cumulative seasonal rainfall and resulting biomass.

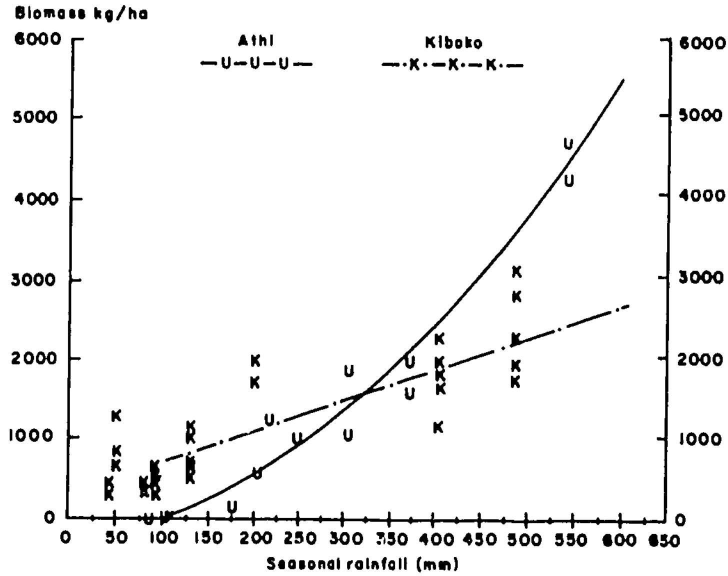
The study in Tsavo National Park was designed to investigate and describe the ecosystem and to "quantify the climate-soil-vegetation-large- herbivore interactions and to develop a model describing these relationships quantitatively" (van Wijngaarden, 1985, p. 149). To this end, herbage productivity was measured in representative vegetation types over five rainy seasons during 1976-78. Data on seasonal rainfall, clipped herbaceous biomass, cover density of the perennial and annual grass as well as the woody component were made available for 88 sample plots, which were used for regression analysis.

The site in the Athi plains was located in the treeless *Themeda* grasslands. The trial design was a factorial with five defoliation frequencies (3-, 6-, 9-, 12- and 15-week cutting intervals) each at three heights of cutting (5, 10 and 15 cm). Treatments were applied from April 1974 to December 1978 covering ten growing seasons. Data on rainfall, evapotranspiration and biomass growth were given for three-weekly periods for the entire duration of the trial. As for Kiboko, only data for the high defoliation intensity (i.e. 5 cm) were used for the analysis. As the medium defoliation frequencies produced the highest biomass, only the cutting intervals of six and nine weeks were included in the analysis. This provided 24 pairs of cumulative seasonal rainfall and its resultant grass biomass production.

For the other locations, relationships between standing biomass and annual instead of seasonal rainfall were available. For the Amboseli plains (Figure 1) the data covered the period 1973-78 (Western and Grimsdell, 1979). Similarly for the Serengeti plains, data were extracted and re-analyzed from Sinclair (1979) and from Braun (1973).

All sites were either protected or were located where grazing pressure was low. Standing biomass was measured through clipping either at ground level or at 5 cm above ground. In most areas, end of season biomass was recorded except in Kiboko (Too, 1985) and in the Athi plains where several defoliation regimes were combined.

Figure 1. The relationship between rainfall and biomass yield at two sites in semi-arid rangeland in Kenya.



RESULTS AND DISCUSSION

Effect of Rainfall

The results of regression analyses of seasonal rainfall on biomass are shown in Tables 1 and 2. The proportion of the variation explained by rainfall ranged from 56 to 99% and was significant in all cases. Linear regressions were as good as quadratic ones except for the data from the Athi plains (Table 2). The response to rainfall increases positively with the total amount per season. In the arid zone (Amboseli) biomass yield is only 3.8 kg DM ha^{-1} per mm of rainfall increasing to 10.7 kg in the tall *Themeda* grasslands in the Serengeti.

However, responses to rainfall in Tsavo were twice as high as in Kiboko (8.0 and 4.1 kg DM/mm of rain respectively) although the latter site receives more rainfall. This is most likely due to differences in grass cover density. The average density in Tsavo was 60%, whereas Too (1985) reported that herbaceous cover in his trial area varied from 15-40%.

Biomass yield at the lower range of rainfall (100-200 mm) was much higher in Tsavo and Kiboko than in the Athi plains (Figure 1). In Kiboko harvesting was confined mainly to rainy seasons; hence for some of the cutting regimes, further growth occurred after the last cut which was carried over into the next season inflating the response to the next rains. However, in Tsavo only new season growth was recorded.

In the Athi plains, a quadratic function gave the best fit, because the data set represented a series of very dry and very wet growing seasons. The trial started towards the end of a long dry period (1972-76), and during the five seasons from December 1974 to January 1977, seasonal rainfall averaged 200 mm producing only 200 kg DM/ha or only 1 kg DM ha^{-1}/mm of rain. Rain fell in small, isolated showers; hence the moisture index (P/E_t) (cf. Sombroek *et al.*, 1982) for any three-week period never exceeded 0.5. This long dry period was followed by 20 months of good rains. From March 1977 up to December 1978 seasonal rains averaged 365 mm and in each of the four seasons there was a moisture surplus ($P/E_t>1$) for at least six weeks. Early in 1978 over 500 mm of rain fell within 3.5 months producing close to 5 t DM biomass (Figure 1).

Soil and Herbaceous Cover

The effect of rainfall on productivity is influenced by soil type and the density of the herbaceous cover. The high biomass of the *Themeda* grasslands in the Serengeti and Athi plains is attributed to the relatively high fertility of the deep Vertisols over basalt (Sombroek *et al*, 1982). Standing biomass of 3-4 t DM/ha^{-1} were recorded on similar soils in Kajiado (Page *et al*, 1975; Karue, 1975) and Masai Mara (Boutton and Tieszen n.d.). The effect of soil type on primary production was studied in Tsavo. For the same rainfall and plant density standing biomass on deep well drained sandy clays was 30-55% percent higher than on shallow gravelly soils (Table 3).

Table 3. The effect of seasonal rainfall, plant cover and herbaceous soil type on end of season standing biomass in Tsavo National Park, Kenya.

	Rainfall (mm)					
	100			300		
	Percent cover					
Perennial grass	10	20	40	10	20	40
Annual grass	10	30	40	10	30	40
	Standing biomass, kg DM ha^{-1}					
Deep soil a/	200	450	760	600	1350	2270
Shallow soil b/	150	290	590	450	860	1760

Derived from van Wijngaarden (1985).
a/ Ferral- and Luvisols.
b/ Cambisols.

The density of herbaceous cover is another important factor influencing primary productivity. In Tsavo, primary productivity increased threefold when grass cover increased from 20 to 80% (Table 3). Low plant cover partially explains the poor response to rainfall in the Kiboko and Amboseli areas. In the latter area herbaceous cover is usually below 10% (Lamprey, personal communication).

Comparison with West and Southern Africa

Re-analysis of the data from West Africa for the rainfall range of 100-600 mm produced a regression equation $Y = -152 + 3.2 x$ ($N = 26$; $R^2 = 0.73$) giving a standing biomass of 800 and 1450 kg DM/ha^{-1} for rainfalls 300 mm and 500 mm respectively. Similar relationships were given by Penning de Vries and Djiteye (1982) for the Sahel in Mali; or very close to those for Amboseli (Table 1). The low Sahel primary productivity was attributed to (1) poor and often sandy soils deficient in nitrogen and phosphorus; (2) high rates of evaporation during the growing season; (3) soil capping increasing runoff and impeding infiltration. As a result, the vegetation consists mainly of short-lived annuals with shallow root systems (Le Houerou and Hoste, 1977), while plant density is usually below 35% and end-of-season standing biomass of annual grasses maximally was 1.0-1.5 t/ha when density was 20-35% (Wagenaar and de Ridder, 1985).

Rutherford (1978) showed that for the *Colophospermum mopane* savanna in Zimbabwe, 300 mm and 500 mm rainfall produced approximately 1000 and 1500 kg DM ha^{-1} or close to the West African data. Much lower productivity was recorded in Botswana (22-23°S) during 1983-84 by Prince and Astle (1986). Although total seasonal rainfall varied from 360 to 530 mm, standing green biomass ranged only from 100-600 kg DM/ha (in 3 sites) with very low cover value (6-20%). High woody cover (mean of 30%) and poor distribution of the rainfall were held responsible for the low herbage growth. Dancy *et al.* (1986) for the same period and at the same latitude in Botswana reported peak standing biomass yields (in May 1984) from 200-1700 kg/ha^{-1}. Low yields were related to low plant density, which was in turn caused by high grazing pressure. Ungrazed areas had dense cover (65%) and yields of 1700 kg DM ha^{-1}, which at an annual rainfall of 550 mm conforms to the equation of Rutherford (1978). This level of productivity is similar to the average peak biomass of 1900 kg DM ha^{-1} reported by APRU (1977) for seven moderately grazed ranches receiving an average rainfall of 450 mm. Earlier work in Botswana confirmed the effect of stocking rate on peak biomass. McKay (1968) found that rangelands with an average rainfall of 300 mm grazed at high and moderate stocking rates for an eight-year period produced 400 and 1360 kg DM ha^{-1} respectively.

The relationships established in Table 1 indicate that productivity is generally lower than given by the equation of Deshmukh (1984) (300 mm:2350 kg DM ha^{-1}, 500 mm:4050 kg DM ha^{-1}), but also that productivity for unit of seasonal rainfall in East Africa is higher than that in either West or southern Africa. The equation of Deshmukh (1984) is distorted by the inclusion of annual and perennial grasslands together from very different environments with both monomodal and bimodal rainfall regimes extending from latitudes 23°S to 4°N. Furthermore, the selective use of data sets of questionable value reduces its predictive value. 1/

CONCLUSIONS

In conclusion, it appears that East African rangelands are more productive per unit of rainfall than those in West and Southern Africa. A combination of factors contribute to this: bimodal rainfall usually falls in well determined seasons of two-three months in length broken by a short dry season. This pattern allows perennial grasses to survive across seasons but encourages short-lived annuals to fill space adding to the overall biomass yield.

Soils are generally more fertile as they are derived from basaltic parent material or when underlain by basement complex surface horizons and are often enriched by volcanic ash deposits.

Finally, extreme caution is required when rainfall-biomass equations that are derived from protected or ungrazed sites are used for prediction of rangeland resources under heavy grazing pressure. Such equations should be adjusted for actual plant cover which is a prime determinant in the rainfall response levels of rangeland vegetations

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1/ A large part of the equation is determined by nine data in Namibia and Marsabit in northern Kenya (cf Herlocher and Dolan, 1980). According to Rutherford (1978, p.629) "...the data from Namibia are maximal values for localized areas. It appears that these data be recognized as accumulated plant mass present at the time of sampling and not as annual production which might be in the order of half or less..." The ten data sets from Marsabit include sparse annual grasslands with 200 mm of rain together with perennial grasslands producing up to 8 t DM ha^{-1} with 700 mm of rain. These perennial grasslands are often found near riverbeds (with run-on moisture)or on isolated mountain sites at 2000 m elevations. These two data sets represent 58% of the total data used to construct the equation. Another six points have been derived from Braun (1973, Figure 5); this figure showed 63 data points covering four different vegetation types two of which were used in Tables 1 and 2 (see equations 5 and 8).

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PRODUCTIVITY OF BEEF STEERS UNDER RANGELAND CONDITIONS IN A SEMI-ARID AREA OF KENYA [1/]

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Abstract

Results from 13 years of continuous grazing of a semi-arid grassland by beef cattle are presented. Liveweight gain per head was found to be independent of stocking rate in the range 2-5 ha per animal. This is because grazing selection to improve dietary intake quality above the gross level in the sward was possible even at the highest stocking rate. Analysis of the rainfall and growth data for the 37 seasons of the study to date showed that 78% of the variation in liveweight gain could be accounted for by the relationship:

Liveweight gain per day (g/hd) = 247.5 x rainfall (mm/day) - 44.5

where the liveweight gain and rainfall figures are derived from the average for each season. The relevance of such a predictive relationship to requirements of settled pastoralists for methods of objective estimation of the long term productive potential of their holdings is discussed.

INTRODUCTION

Approximately 85% of Kenya can be classified as arid to semi-arid, receiving less than 750 mm rainfall in four out of every five years (Griffiths, 1962). The traditional land use in these areas has been nomadic pastoralism, as with the unacceptably high risk of crop failure, settled crop production was not practicable under the low and very variable rainfall regime. However, nomadic pastoralism can only provide for security of food supply in such a very inhospitable environment if the necessary free movement of people and their stock is possible through low population density and where the land is not registered for ownership (Henning, 1960; Allan, 1965). Efforts by both Government and private development agencies towards improvement of human health and veterinary services, particularly over the last 30 years have considerably increased the pressure on the land in the arid and semi-arid regions of Kenya. This has been combined with the efforts by the Government to register land titles, either on an individual or group basis, in order to provide collateral for development loans and to make the provision of government services easier in a settled situation. A major result of these actions has been to limit the possibilities for movement as a strategy to cope with the effects of drought on feed and water supply to stock. Problems of periodic shortages of grazing; and of water under the settlement

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1/ Views expressed in this paper are not to be considered as representing the official policy of Kenya Agricultural Research Institute or the Government of Kenya.

programme have to be dealt with on the individual holding *in situ*.

Although the subsistence requirements for the settled pastoralists in the semi-arid areas are likely to remain centred on milk, there is evidence that provision of good marketing facilities can result in stock sales and considerable changes in herd management and in food purchases and consumption patterns (White and Meadows, 1981). Past strategies of maintaining apparently high stock numbers to reduce the risks of complete stock losses in drought, together with a high proportion of mature females in the herd to provide for milk production on a year-round basis are less justifiable or practical in a settled situation. Where stock numbers are high in a settled situation, drought effects may be expected to be severe, so it is desirable that the long-term animal production potential of particular land holdings are estimated using objective methods. This may provide a basis for recommendations as to the stock numbers and herd structure appropriate to the level of risk acceptable to those depending on the holding for their livelihood.

The present paper presents data from a long-term study in a semi-arid area of Kenya of the growth of beef steers in relation to the pattern of rainfall distribution and amounts. It will be suggested that the results of the study indicate a possible methodology for the objective assessment of the long-term production potential of such rangeland sites, where the climatic database is adequate.

METHODS

Field data were collected at the Rohet Ranch sub-station of the Kenya Agricultural Research Institute, situated about 15 km from the Athi River Township (Lat. $1^{o}20$'S Long. $37^{o}05$'E). The site is about 1500 m altitude. Rainfall is bimodal, falling mainly in November/December and March/April/May with an average of about 580 mm being recorded over a period of fifteen years. The rainfall is typically highly variable both annually and seasonally, and vegetation growth closely follows its distribution. Evaporation potential is generally high, with less than 5% of the months having a Rainfall/Eo ratio greater than unity. Under the existing standard classification of East African rangelands the site lies in Ecozone IV (Semi-arid) (Pratt *et al*, 1966). In the more recent agro-ecological zone classification adopted by the Kenya Soil Survey the site lies on the boundary between the Livestock-Sorghum Zone (UM5) and the Upper Midland Ranching zone (UM6) (Jaetzold and Schmidt, 1983).

The soils at the site are generally shallow sandy-clay loams derived from transported materials (Scott, 1962; Sombroek *et al.*, 1982). Vegetation is an open grassland dominated by *Themeda triandra* Forsk. The conditions at the site are representative of extensive areas of Kajiado, Narok and parts of Machakos districts, traditionally used by the Maasai tribe.

The work was designed to measure the growth performance of beef steers under a range of set stock rates. For the first eleven years of the trial rates were 2, 3, 4 and 5 hectares per steer. For reasons which will be discussed further below, these stocking rates were increased to 1.33, 2.0, 2.67 and 3.33 hectares per head thereafter. The initial rates were chosen following discussions with local ranchers and extension personnel and agree with the estimates made for ecozone IV (Pratt *et al.*, 1966; Jaetzold and Schmidt, 1983) and with estimates based on rainfall distribution (Jahnke, 1982).

The animals used were F_1 cross steers from *Bos indicus* (local Boran type) dams and *Bos taurus* (Hereford type) bulls, such crosses being typical of the type of animals to be found in the commercial ranch in this part of Kenya. The animals entered the trial at about 15 months of age and were removed at about 33-36 months or at a weight of 450-500 kg. Liveweight gain of the animals was considered a good indicator of pasture condition. During the 13 years of the trial, eight series of animals were used. Set stocking was used throughout the trial as the limited data available from tropical areas did not show any evidence in favour of rotational grazing ('t Mannetje *et al.*, 1976).

Also, set stocking relates closely to current land usage and will provide baseline data, with the more resource-demanding rotational systems being tested in later studies. Because of predator risks the experimental animals were removed to a secure night paddock during darkness, so they grazed from 0630 to 1830 hours each day.

For reasons of cost and availability of land, only a single paddock for each stocking rate was used, with four animals per stocking rate initially, raised to six in the twelfth year. All animals were sprayed against ticks twice weekly and were routinely vaccinated against prevalent diseases. Weights for each animal were recorded at the same time each week following overnight fasting and withdrawal of water.

Samples for estimation of dietary composition were obtained from oesophageal fistulated animals similar to those used in the grazing study. Sampling was carried out for about 30 minutes at each sampling, with either three or four animals being used twice a day for three days.

Analysis of the collected material was confined to laboratory chemical analysis using standard methods (Van Soest, 1963; and AOAC, 1970) with the data being calculated on an ash-free basis in an attempt to reduce the effects of salivary contamination (Marshall *et al.*, 1967). Twenty 2 m x 1 m sample quadrats were harvested at random per paddock by cutting at about 5 cm height to give an indication of the composition of the overall sward at the time of the oesophageal sampling.

RESULTS

Figures 1 to 8 indicate the trend of liveweight gain for each of the eight series of animals for the four stocking rates used, with the cumulative rainfall being also shown on each of the figures for the relevant period. The weights are indicated on a three-week basis for clarity of presentation. The generally close similarity in performance between steers on the different stocking rates is notable. The pattern of growth was closely associated with the pattern of rainfall.

Figure 1. Liveweight gain/rainfall, animal series 1 (3.6.74-2?.1.75).

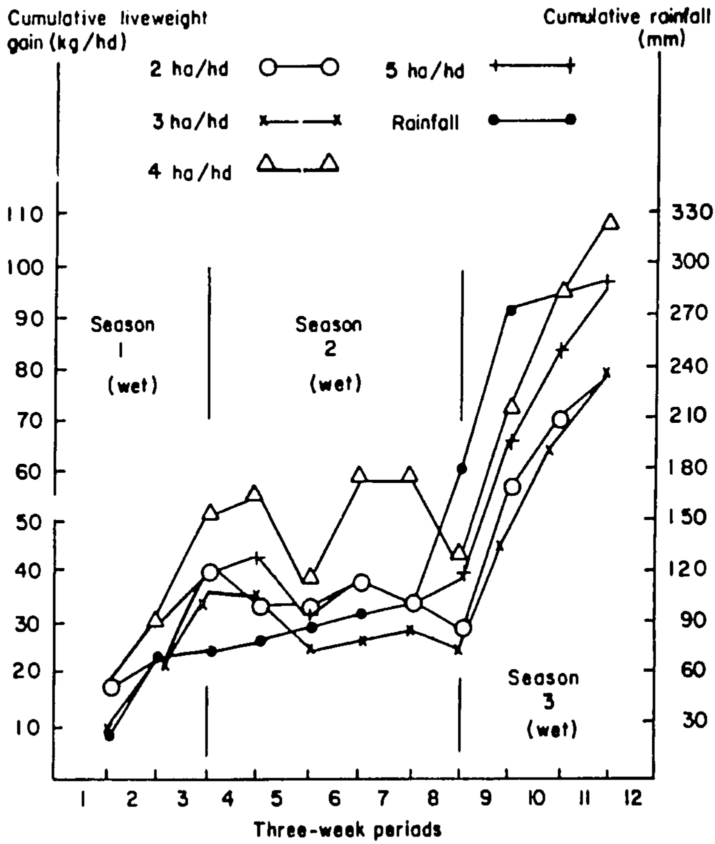


Figure 2. Liveweight gain/rainfall, animal series 2 (17.2.75-30.8.76).

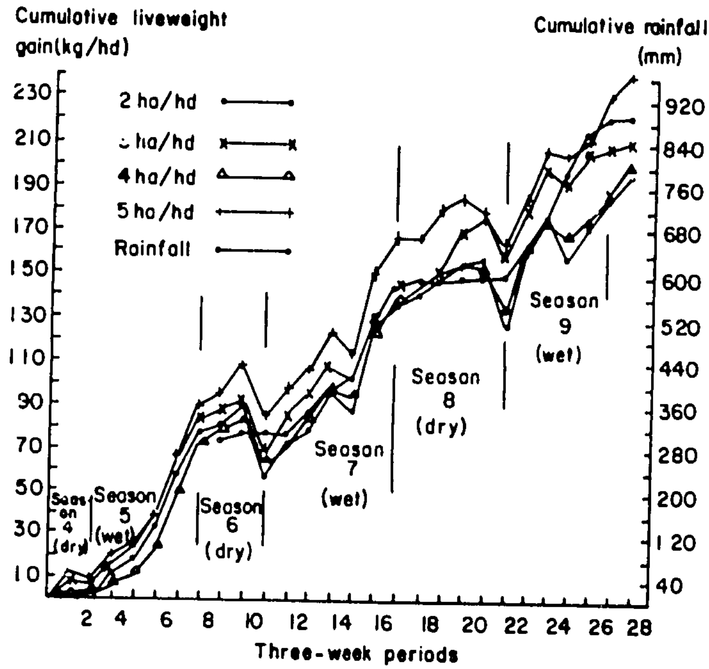


Figure 3. Liveweight gain/rainfall, animal series 3 (20.7.77-11.9.77).

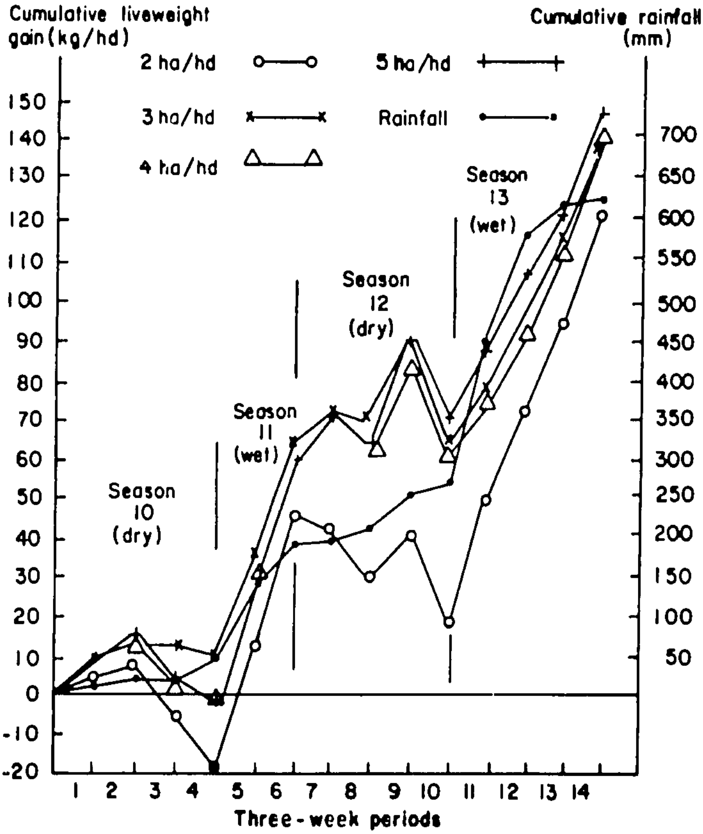


Figure 4. Liveweight gain/rainfall, animal series 4 (1.8.77-8.1.79).

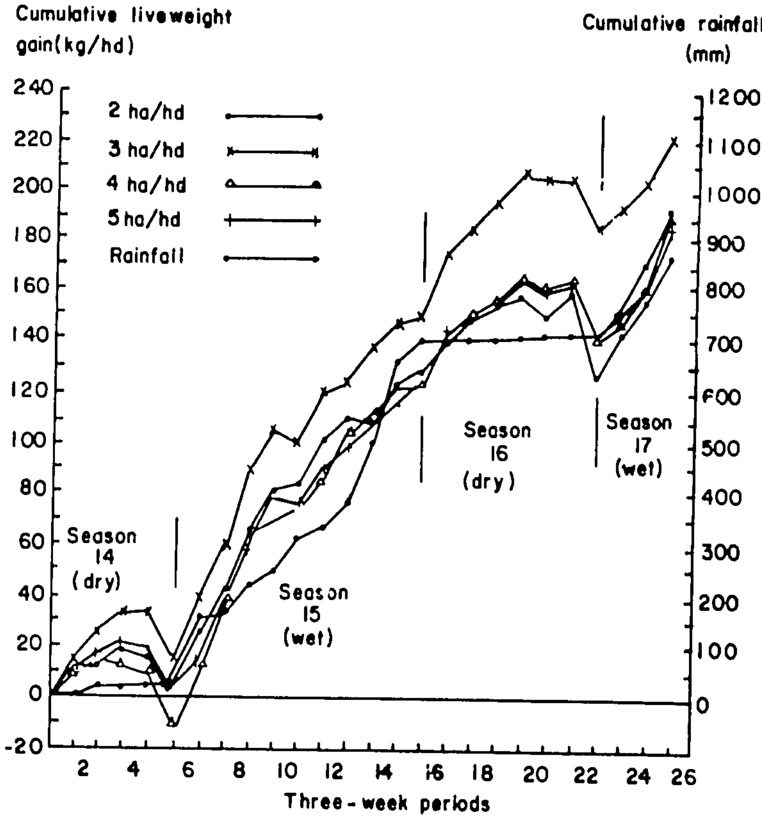


Figure 5. Liveweight gain/rainfall, animal series (11.1.79-22.3.81).

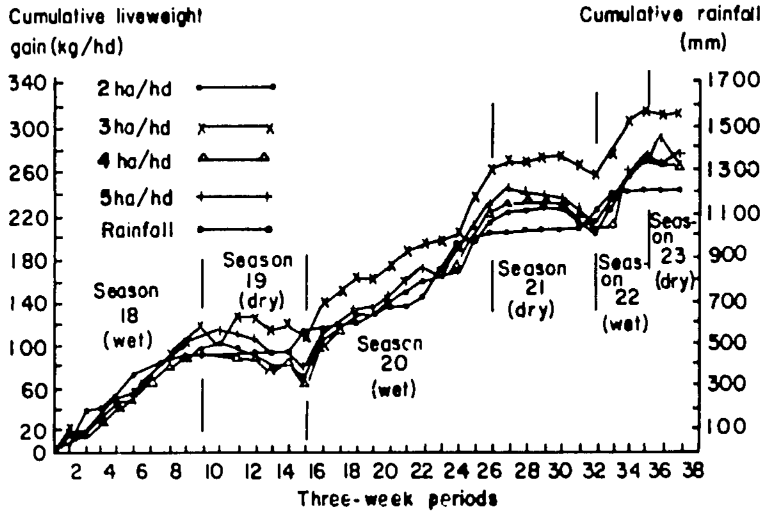


Figure 6. Liveweight gain/rainfall, animal series (16.3.81-21.6.82).

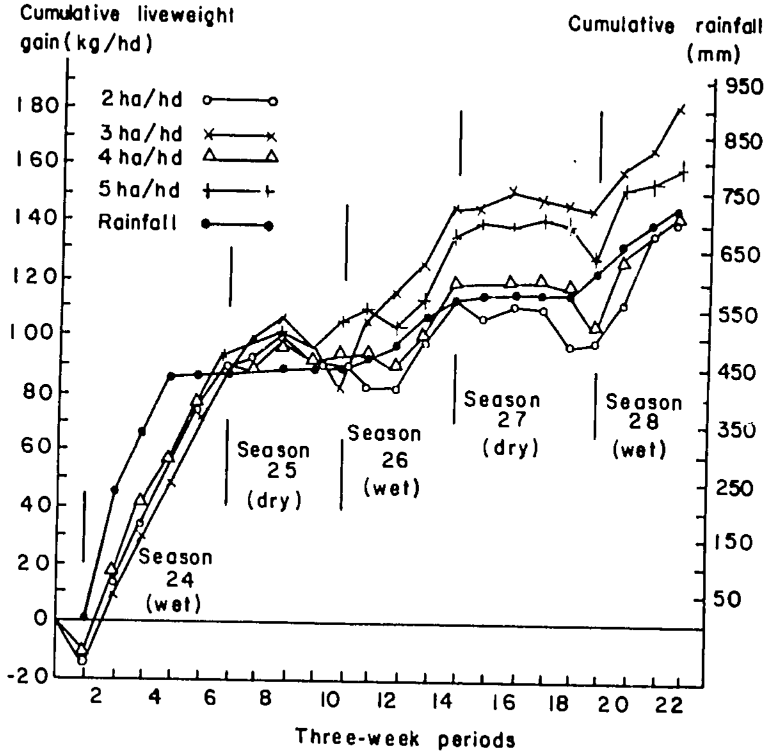


Figure 7. Liveweight gain/rainfall, animal series (12.7.82-23.7.85).

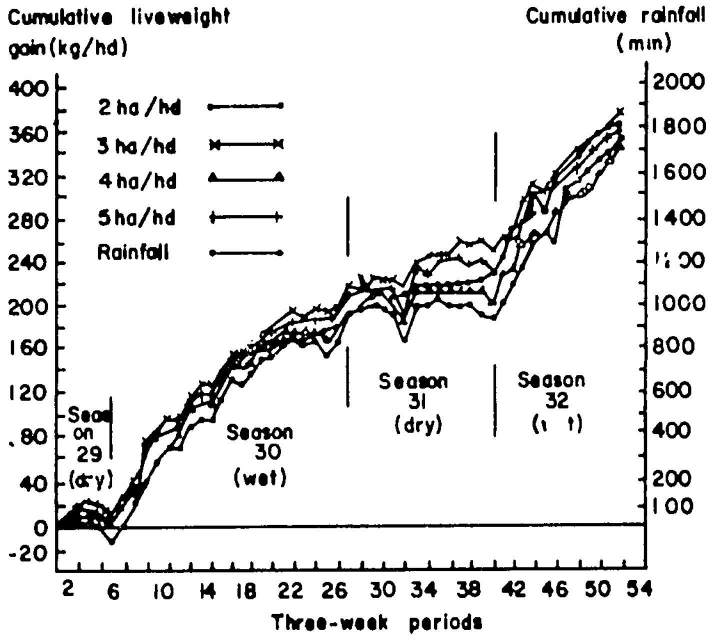
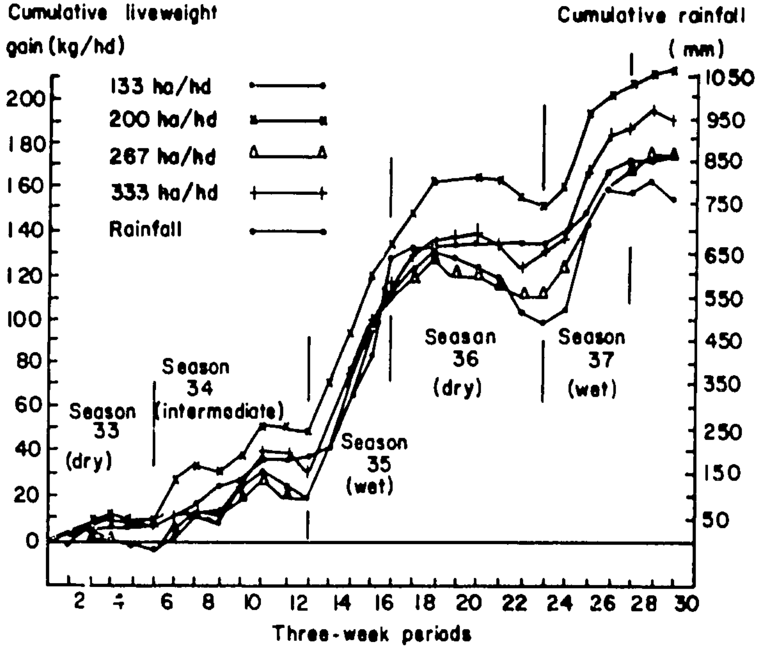


Figure 8. Liveweight gain/rainfall, animal series (9.7.85-30.3.87).



Tables 1 to 6 indicate the results of the dietary quality examination, using crude protein as the quality parameter, derived from the fistula samples, together with an indication of dietary selection practised by the animals as represented by the differences between sward and fistula samples.

Table 1. Protein content of sward and oesophageal fistula samples, June 1974.

Component		Stocking rate ha/head					
(Ash free basis)		2	3	4	5	Mean	S.E.
Crude protein	% fistula	8.0a	8.2a	8.5b	8.1a	8.2	0.1
	% sward	5.8a	6.0a	6.0a	5.9a	5.9	0.1
	% increase	37.9	36.7	41.7	37.3	37.0	-

Table 2. Protein content of sward and oesophageal fistula samples, October 1974.

Component (Ash free basis)		Stocking rate ha/head 2	3	4	5	Mean	S.E.
Crude protein	% fistula	4.5a	5.3b	6.2c	4.7a	5.2	0.1
	% sward	3.5a	3.5a	3.8a	3.4a	3.6	0.2
	% increase	28.6	54.4	63.2	38.2	44.4	-

Table 3. Protein content of sward and oesophageal fistula samples, May 1975.

Component (Ash free basis)		Stocking rate ha/head 2	3	4	5	Mean	S.E.
Crude protein	% fistula	12.1a	12.4a	11.1b	12.6a	12.1	0.3
	% sward	9.4a	9.5a	9.5a	9.6a	9.5	0.3
	% increase	28.7	30.5	16.8	31.3	27.4	-

Means with the same subscript letter do not differ significantly at P=0.05 (Duncan, 1955).

Table 4. Protein content of sward and oesophageal fistula samples, August 1975.

Component (Ash free basis)		Stocking rate ha/head 2	3	4	5	Mean	S.E.
Crude protein	% fistula	6.2ab	6.5b	6.6b	5.5a	6.2	0.3
	% sward	4.1a	4.2a	4.4a	4.1a	4.2	0.3
	% increase	51.2	54.8	50.0	34.1	47.6	-

Table 5. Protein content of sward and oesophageal fistula samples, September 1974.

Component		Stocking rate ha/head					
(Ash free basis)		2	3	4	5	Mean	S.E.
Crude protein	% fistula	7.3a	8.0b	8.1b	6.8a	7.6	0.3
	% sward	5.1a	6.2b	5.4a	5.1a	5.5	0.3
	% increase	43.1	29.0	50.0	33.3	38.2	-

Table 6. Protein content of sward and oesophageal fistula samples, June 1977.

Component		Stocking rate ha/head					
(Ash free basis)		2	3	4	5	Mean	S.E.
Crude protein	% fistula	10.9a	10.8a	10.5b	10.5a	10.7	0.3
	% sward	8.4a	8.5a	8.6a	8.5a	8.5	0.4
	% increase	29.8	27.1	22.1	23.5	25.9	-

Means with the same letter do not differ significantly at P=0.05 (Duncan, 1955).

DISCUSSION

The results for the dietary composition and selection presented in Tables 1 to 6 indicate that there was apparently very little difference in the quality of diet eaten by the animals on the different stocking rates at different seasons of the year covering dry, wet and intermediate season conditions. Throughout the whole of the initial eleven years of the trial there was no indication of any statistically significant differences in per animal performance across the stocking rates so that performance at 2 hectares per head was as good as at 5 hectares. The inference to be drawn from this is that quality of the diet had the greatest effect on performance, with quantity of herbage available being of lesser importance, provided it was sufficient so that dietary selection could be practised effectively. It has been suggested that the relationship between animal performance and stocking rate would be highly site-specific and not conform to the simpler linear (Jones and Sandland, 1974) or culvilinear (Mott, 1960) relationships proposed earlier. To test what would happen to the sward and animal performance an increase in stocking rate in the present trial was made at the end of the eleventh year in order to determine whether selection would still be effective at higher stocking rates. Since long-term degradation of the sward had not been observed up to that point it was postulated that it might occur as at higher stocking rates together with sward damage by trampling and soiling by dung and urine.

The results of the eighth series of animals to date (Figure 8) do not show any clear indication of a reduction of performance in the 1.33 ha/head stocked paddock so that the effects just mentioned may not yet become evident over the time span of 18 months.

The general association between the performance of the animals and the pattern of rainfall distribution suggests that a predictive relationship may be derived from the results so far obtained. The growth curves were broken down into a series of wet seasons associated with the presence of rainfall, interspersed with periods of little or no rainfall in the dry seasons, the seasons being indicated in Figures 1 to 8. An earlier analysis of the growth and rainfall data (Potter, 1985) indicated a time lag effect in the relationship between rainfall and liveweight gain. Due to the time taken for the vegetation to respond to the onset of the rains, any rain falling in the three-week period immediately before the weight measurements appeared to be less influential than rain that had fallen three weeks earlier, that is from three to six weeks before weighing. Indeed, the analysis indicated that rainfall in the period immediately before the weighing was negatively correlated with growth. This may be explained by a loss in weight associated with the onset of rains resulting from a combination of reduced temperatures and a great change in the solid/water ratio and nutritive content of the diet (French, 1956; Denis *et al.*, 1976).

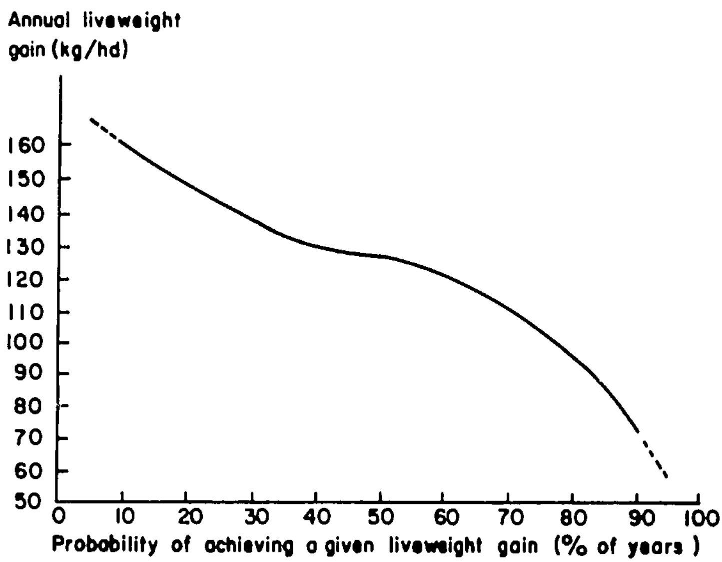
Using a three-week lag as discussed above, the data presented in Figures 1 to 8 were analysed further by examination of the growth rates in particular seasons in relation to the quantity of rainfall during the season. The seasons used are indicated on the respective growth curves as indicated on the figures. Since the results for all four stocking rates were combined, analysis of variance for the performance of the separate rates for each series of animals indicated no statistically significant differences ($P=0.05$). Eq. 1 indicates the relationship derived between daily rainfall during the seasons and liveweight gain per day. The data for the eighth series of animals were included in the derivation of the relationship even though the mean stocking rate was 2.33 ha per head as opposed to 3.66 ha per head for the earlier series as analysis indicated that all eight series could be considered part of one homogeneous data set.

$$Y = 247.5\ (\text{S.E. } 22.4)\ X - 44.5\ (\text{S.E. } 49.9)$$
$$(\text{-Equ. } 1)\quad R^2 = 0.78$$

where Y represents daily liveweight gain in grammes per head and X represents daily rainfall in mm. A linear relationship, which accounts for 80% of the variation in liveweight gain suggests that rainfall data may be useful as a basis for predicting animal performance. Kenya is fortunate among developing countries in having a relatively large database of long-term rainfall records (up to 80 years) even in some of the semi-arid areas.

Even though there may be an element of bias in the siting of the rainfall stations in positions which may be somewhat wetter than the surrounding area (Potter, 1987), the data were used to calculate the probability of seasonal rainfall for the Rohet Ranch site combined with the Athi River Railway Station site some 15 km distant over a period of 65 years. Using a relationship derived as above the probability of annual livestock production levels were calculated on a long-term basis. Figure 9 indicates the probability of achieving a particular level of annual productivity per animal using the long-term rainfall data.

Figure 9. Long-term probability estimate for annual liveweight gain per head for beef steers at Rohet Ranch.



The above analysis assumes that the quantity of herbage available to the animal is not limiting selective grazing during any one year. Up to the highest level of stocking used to derive the relationship (Eq. 1) no restriction in selective ability was evident, at least for the first eleven years of the study. The term changes in the sward vigour which may result in a decline in quantity of production or alteration in sward composition and therefore selection possibilities, but to date these have not become apparent. Direct measurements of sward productivity may not be adequate to indicate any such decline as the method of harvest may have a considerable effect on the yield figure measured. This point has been discussed in a related paper (Potter and Said, in press).

It is intended that this study will be followed by others which will provide the necessary data to test the methodology at other sites, as no similar data are at present available from any similar long-term study in the region. Should the methodology prove to be generally applicable, even outside East Africa, the potential productivity for sites will be predictable to a level of accuracy useful for management planning recommendations.

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CLASSIFICATION OF KENYA RANGELAND

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Abstract

There is need for another committee to be set up to review the boundaries of the existing ecological zones. The East African Range Classification based their classification on ecological potential of the land and the description of the existing vegetation with emphasis on nature and relative contribution of woody plants and grass.

Detailed work must be carried out on broad eco-climatic zones so that they are subdivided on physiographic and edaphic criteria to yield precise ecological land units. The author has tried to subdivide the existing ecological zones into 29 ecological units based on total and monthly rainfall distribution. Also used is the livestock utilisation of these areas. The latter criterion is useful when it comes to planning. Rainfall controls soil formation and its potential, and that is why it became a useful tool in the subdivision also.

INTRODUCTION

The East African Range Classification Committee which was set up to classify rangeland ran into a problem because those who had tried to classify rangeland before them used grassland composition (Pratt and Gwynne, 1977). This approach was not satisfactory because the variation in grass composition in East Africa is so great that to classify rangeland solely by reference to one or two of its constituent grass species would give an incomplete idea of its character.

The committee then used three characteristics to classify rangeland; soil moisture availability, climax vegetation and land use. They came up with six ecological zones. Rangeland was divided into three zones i.e. IV, V and VI. There has always been a need to review these zones because variation in productivity is too great. For example, two areas may receive a total of 500 mm of rainfall annually.

One area may receive all that rain in one month while another area may receive it in two months. These two areas will differ in their land potential and grass composition. There has therefore been a need to review these ecological zones for proper planning and effective management.

Kenya Rangeland Ecological Monitoring Unit (KREMU) divided rangelands of Kenya into 44 eco-units based on area occupied by animals belonging to a group of people all year round. This criterion of land use was not enough to delineate rangeland into ecological units which could later be used for planning purposes. Other factors like soil types, rainfall, soil moisture, and vegetation types had to be considered.

METHODOLOGY

The methodology involved looking at those factors already mentioned to see how they control or affect land potential.

Soil Types

Soil undergoes a series of development stages as climate and organisms act upon the original rock or parent material (Stoddard and Smith, 1955). Thus soil alone cannot influence the productivity of an area because its development is controlled by other factors. Soil which has developed through interaction of high temperature, low rainfall and little organism will be poor in plant nutrient.

Vegetation Types

Vegetation is the product of its environment. The environment includes land form, soil, climate, animal and man. Often, of course, the present vegetation represents a stage of regression from a more highly developed or rigorous community which has been brought under stress, perhaps through use by man.

Rainfall

Rainfall readings were divided into seven segments of 100 mm interval from 200 mm to 800 mm. Isohyets were drawn to join all areas with the same readings. Another rainfall parameter which was used was the monthly distribution.

Soil Moisture Pattern

Soil moisture is closely related to grass production. Cassady (1973) reported that storms which produced 175 mm to 280 mm of rain within 30-60 days soaked the soil profile to depths of 120-180 cm. Thus soil which is capable of retaining most of the rain water and make it available to plants has higher plant production than either sandy soil or soil with hard layer which does not allow much percolation. Soil moisture was not used because not much research has been done on the major soils.

Land Use

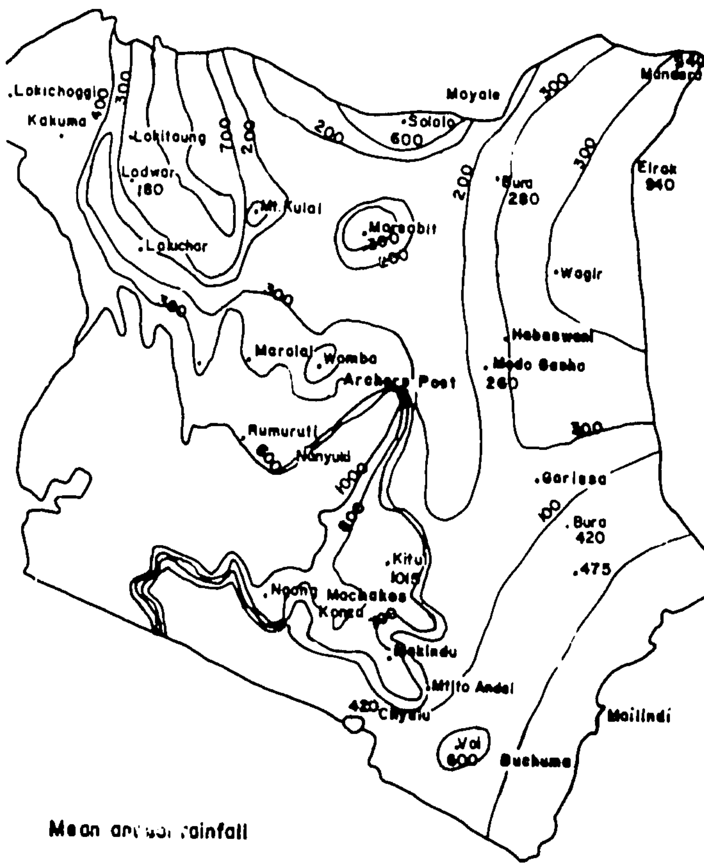
Generally land use in most areas of rangeland is pastoralism. The area was used by either one ethnic group or a section of that group without coming out of it unless it was very necessary.

RESULTS

Isohyets of 500 mm, 400 mm, 300 mm and 200 mm were used as boundary lines. Another boundary line was added showing livestock movement by one ethnic group or a section of a group. Thus a few modifications were made to the isohyets to accommodate these movement areas. For instance, Ewaso Ngiro was curved out of Mandera and Khorof Harar because of increased soil moisture from the underground river.

The whole rangeland was divided into 29 ecological units, as shown in Figures 1, 2 and 3. The present 29 ecological units are manageable units as they are being used at the moment. There is some relationship between the boundaries of land potential and rainfall monthly distribution.

Figure 1. Rainfal] map of Kenya.

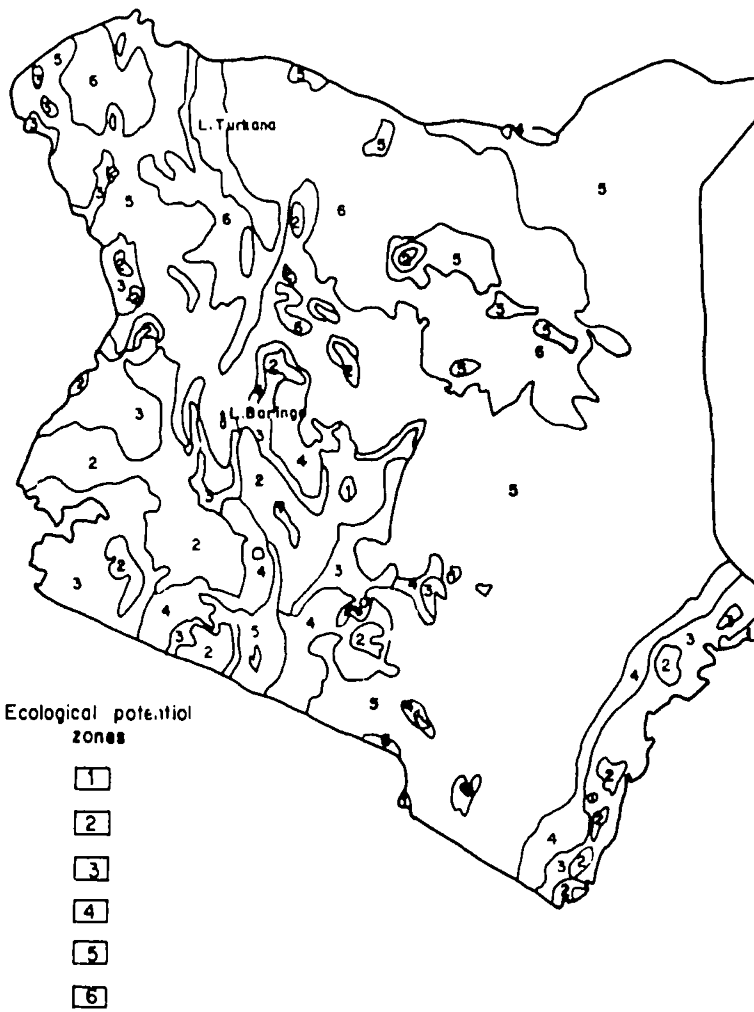


Ecological Units

1. Lotikipi Plain

This eco-unit covers the upper half of Turkana District. The rainfall ranges from 300-500 mm annually, and it decreases from the Sudan border to Lake Turkana. The driest months are January through March while the wettest are April through June. The other months receive a little rain. Bush density also decreases with rainfall while the Lotikipi Plain itself is open grassland. The western bushland has grasses dominated by *Sporobolus continis* and *Eragrostis racemosa*. The central plain is dominated by palatable grasses like *Echinochloa haploclada* and *Chloris virgata* but when misused, the area is invaded by *Dactyloctenium aegyptium*, *Aristida mutabilis*, *Fupalia lappacea*, *Barleria accanthoides* and *Cleome hirta* (Olang, 1984b).

Figure 2. Ecological zones of Kenya.

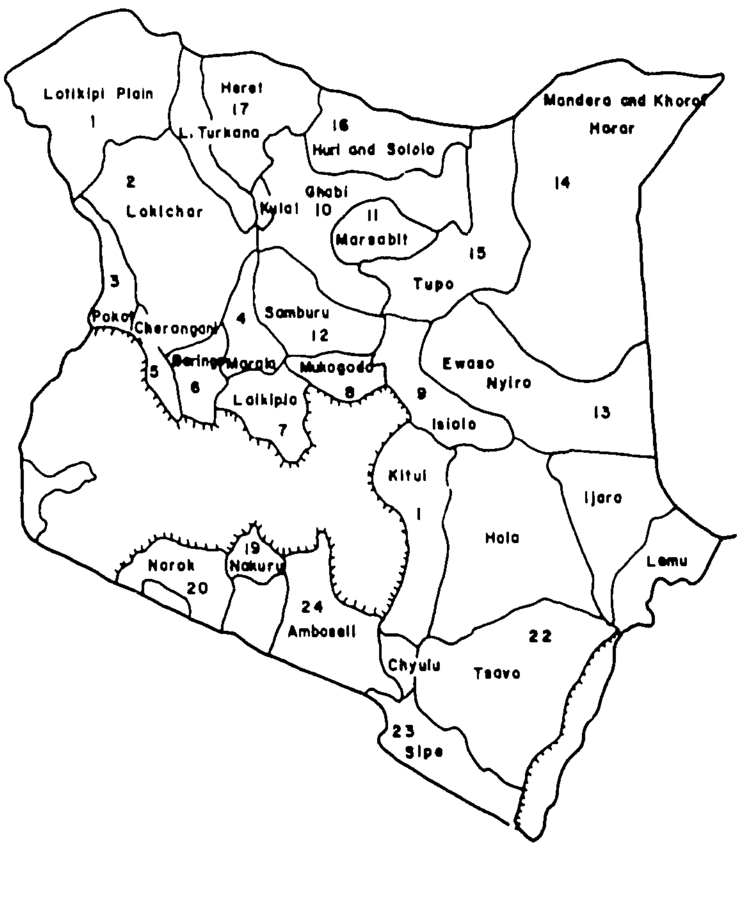


Livestock concentrate in the highland around Lake Turkana during the dry season of January through March but move down in the plain during the rainy season. From there they move towards the Sudan border from July onwards, but cattle rustling interferes with the grazing in that area.

2. Lokichar Eco-unit

This is the lower part of Turkana District. Rainfall ranges from 500 mm on the western border to below 100 mm around the town. The dry central scrubland is divided almost in half by the Turkwel river. The area receives rainfall in April and May and very little along the Uganda border in June. The short rains of November and December are hardly experienced because of the prevailing wind which blows from Lake Turkana to the western border from August through December.

Figure 3. Ecological units in Kenya.



Riverine vegetation are dominated by *Acacia tortilis*, *Hyphaene coriacea* and *Salvadora persica*. Areas away from the river are dominated by *A. reficiens*, whose density and tree height increases with increasing rainfall.

The area is dominated by annual plants like *Digitaria velutina, Aristida mutabilis, Dicoma tomentosa, Pupalia lappacea, Zaleya pentandra and Eragrostis cilianensis*.

D. velutina dominates the western border, while *A. mutabilis* dominates rocky areas and *E. cilianensis* is the common grass found in the remaining areas. Further to the west and the southern borders perennial grasses like *Panicum maximum, Digitaria milanjiana* and *Echinochloa haploclada* are found. When the area is misused, it is invaded by *A. mutabilis* and Cleome monophylla.

3. Pokot Eco-unit

This eco-unit forms the northern end of the Charangani hills. Rainfall ranges between 500 mm and 700 mm annually. The area has thick bush dominated by *Acacia tortilis, A. reficiens, A. brevispica* and *A. mellifera*. Grasses are mainly desirable species like *P. maximum, Chloris gayana* and *Cenchrus ciliaris*.

4. Maralal Eco-unit

This area runs from Sukuta Marmar through Maralal town up the northern end of the district. There is a ragged valley bordering Turkana District where vegetation is still in its potential. Rainfall ranges from 300 mm to 600 mm. The area east of Maralal hill receives the lowest amount of rainfall. Rainfall falls during the months of March to April and October to November.

Desirable grasses like *Themeda triandra, C. dactylon* and *D. milanjiana* are systematically being replaced by *Aristida adoensis* and *Harpachne schimperi* which are increasers and *Microchloa kunthii* which is an invader.

5. Cherangani Eco-unit

This eco-unit mainly comprises the eastern footslopes of the Cherangani hills and the Kerio Valley. The western side of the river is dominated by *Acacia tortilis* while the eastern dry side is dominated by *A. mellifera*, and the grasses are mainly *C. dactylon, A. mutabilis* and *Urochloa brachyphylla*. There is high concentration of livestock in the valley because of water availability.

6. Baringo Eco-unit

This eco-unit lies between the Tugen hills and Laikipia escarpment with Lake Baringo centrally located. The vegetation cover is good to the south around Chemogoch where grasses like *T. triandra, E. superba* and *C. dactylon* are still available. The vegetation cover and palatability improves again north of Lake Baringo. The area around the lake has been overgrazed and is dominated by *Acacia adoensis, Sporobolus fimbriatus, Microchloa kunthii, Tragus terrestris* and *Dactylocteneum aegyptium*.

Rainfall ranges between 300 mm and 500 mm, decreasing from south to north.

7. Laikipia Eco-unit

This eco-unit is bordered by the Ewaso Nyiro river on the north, Aberdares mountains to the south and Mt. Kenya to the east. Its rainfall ranges from 400 mm to 600 mm annually, decreasing northward. The grass cover is dominated by *Themeda triandra* and *C. dactylon*. *Cynodon* increases as *Themeda* is overgrazed, but the area is generally still in good condition as most of it is divided into ranches which are well managed. *Acacia drepanolobium* is the dominant woody species. Areas which remain dry for longer periods support short flat-topped *A. drepanolobium* while the more fertile areas that remain moist for longer periods support very tall *A. drepanolobium*. Areas which are overgrazed, seen mostly towards Rumuruti, are dominated by unpalatable species such as *H. schimperi* and *A. adoensis*.

8. Mukogodo Eco-unit

This is the eastern end of Laikipia district where the Ndorobo ethnic group lives. In this hilly area human population has greatly increased.

Although the area gets good rainfall, overgrazing and the hilly nature of the area has greatly accelerated soil erosion. Woody vegetation is being depleted through charcoal burning. *Harpachne schimperi* and *Microchloa kunthii* are replacing palatable species such as *T. triandra*.

9. Isiolo Eco-unit

This eco-unit runs from the Somali strip on the western end through Shaba and Buffalo Game Reserve to Modogashe town. Rainfall and land potentiality decreases from west to east. The long rains fall between April and May while the short rains fall in November. Herbaceous plants are dominated by *T. triandra*, *P. maximum*, *Cenchrus ciliaris*, *Sporobolus marginatus*, *Panicum coloratum* and *Chloris roxburghiana*. *C. roxburghiana* and *C. ciliaris* dominate around Garba Tula while *C. dactylon* dominate in the northeast of Merti town.

Areas which have been overgrazed around Garba Tula are dominated by *Aristida papposa* and *Digitaria velutina*. The woody plants are dominated by *Commiphora* sp. while areas around Kula Mawe through to the Shaba Game Reserve is dominated by *Acacia* sp.

10. Chalbi Desert Eco-unit

This eco-unit can easily be divided into three sub-units. The Kaisut area has quaternary sediment and lies south of Marsabit hill. The second is the old lake bed of Lake Chalbi which is mostly covered by saline alkaline alluvial materials. The last is the recent alluvial and aeolian material overlying the eastern and north-western edges of the Chalbi desert (Herlocker, 1979).

The desert forms a swamp of an interior drainage system with perennial springs at the edge of the desert.

Long rains fall in April and May while short rains fall in November. Evapotranspiration in this area is so high that the rains support mostly annual species. The desert supports salt-loving species like *Sueda monica* while other areas support annual grasses such as *Aristida papposa*. While one view was that the area was dominated by *Chrysopogon/Aristida*, Heady (1960) thought *Aristida* sp. was the most dominant grass. Pratt and Gwynne (1977) called the area barren land. Composition and production of grasses vary greatly from place to place and from time to time reflecting high variability in rainfall (Herlocker, 1979).

11. **Marsabit Eco-unit**

This eco-unit is found in two areas: around Marsabit hill and Mt. Kulal. It is restricted to the upper elevation of these mountains.

(a) *Marsabit*: The southern and eastern slopes of the mountain are wetter than the others (Herlocker, 1979). The deciduous trees consist of species like *Commiphora* spp. and *Croton dichogamus*. *Harrisonia abyssinica* is a common shrub. Fire seems to be an important factor in degrading the vegetation. Grasses are mostly *Dichanthium/Themeda*, but overgrazed areas have unpalatable herbs or grasses such as *Eragrostis tenuifolia* and *Chenopodium* spp.

(b) *Mt. Kulal*: Like Marsabit rainfall is higher and better distributed than other parts of the district. Herlocker (1979) noticed that perennial grasses grow where openings occur in the bush canopy. Grasses are especially like those found in Marsabit. Most of the pastoralists who bring their livestock up-hill in the morning during the dry season descend in the evening because of cold nights.

12. **Samburu Eco-unit**

This eco-unit runs from the Maralal (Karisia) hills to the Wamba and Oldoinyo hills to the east of the Elbarta plains. Animals graze in the Suare and Ilponyeki plains during the wet season but come to water at Seyia river. During dry seasons most of the animals are taken into the hills while others go to Kom area. Range conditions in this area seem to be decreasing as readings on herbaceous cover showed a change from 42% in 1961 to 31% in 1970, then 22% in 1980. Plant composition of desirable species also changed from 68% in 1961 to 49% in 1970, then to 33% in 1980 (Skovlin, 1980).

Ilponyeki plain is dominated by *Cynodon dactylon* and *Aristida papposa*.

13. **Ewaso Ngiro Eco-unit**

This eco-unit receives the same amount of rainfall as Mandera and Khorof eco-units except it gets more water through the drainage system. Lagh Bogal which starts from the border of Marsabit and Wajir around Tamsa swamp runs through the Boji plain and ends at the Kenya/Somalia border. The other is Lagh Awaro which forms the northern end of the unit. Lagh Dera is actually the lower reaches of Ewaso Ngiro where water from the river runs underground. It has the highest number of perennial grasses. *P. coloratum*, *Sporobolus* spp., *A. adoensis*, *Rhynchetrum* spp., *Enteropogon macrostachys* and *Eragrostis caespitosa* have been recorded (Olang and Karime, 1981).

14. Mandera and Khorof Eco-units

From the Ethiopian border the area is mostly rugged with a lot of small water streams from west to east. There are a number of watering points along the international borders with Ethiopia and Somalia. Herbaceous cover in the south is dominated by *Justicia flava*, *Aristida kenyensis* and *Aristida adscensionis*. Rainfall ranges between 300 mm to 400 mm annually although the central part falls below 300 mm.

15. Tupo Eco-unit

This eco-unit lies below Marsabit and Mandera/Khorof eco-units. It remains wet longer than the areas around. The good grass cover found in the Lagh bogal drainage system starts from Tamsa swamp which is in the southern end of the unit. *C. dactylon* is one of the most important perennial species.

16. Huri and Sololo Eco-unit

The hills are the southern end of the Ethiopian hills with the rainfall near the border being more than 800 mm. The hills do not have extensive areas of closed forest, but many valleys, gullies and steep hillsides have dense cover. Among the common trees are *Croton macrostachyus*, *Euphorobia candelabrum*, *Olea africana* and *Bauhinia tomentosa*.

Open hills and gentle slopes in the wetter western slopes carry plants like *Combretum molle*, *Lannea* spp. and *Ozoroa* spp. Much of the Hurri hills is grass covered which is edaphically controlled. Soils are heavy clay, with impeded drainage and frequent flooding (Synott, 1979). *Themeda/Chrysopogon* grassland occurs at the eastern base and to the northeast of Hurri the hills (Herlocker, 1979).

17. Ileret Eco-unit

This eco-unit includes Sibiloi National Park where the herbaceous cover is dominated by *Dactylocteneum aegyptium* and *Aristida mutabilis* which are both annual with one perennial *Sporobolus ioclauds* (Odhiambo, 1981). Other grass species include *Enneapogon cenchroides*, *Aristida adoensis*, *Tetrapogon tenellus*, *Tragus berteroniaus* and *Stipagrostis uniplumis*. Further north towards Sabarai the number of species and percent cover decreases. *A. mutabilis* becomes dominant. Other species like *Tetrapogon tenellus* and *Tragus berteronianus* are found in low depression areas where soil moisture is higher.

18. Kitui Eco-unit

This eco-unit covers the whole of Kitui District, the northern part of Machakos and parts of Embu and Meru districts. Livestock movement is not so conspicuous here because of cultivation and some improved ranches.

Kitui District used to support perennial grasses like *P. maximum*, *Sehima nervosum*, *H. contortus*, *E. superba*, *E. macrostachyus*, *D. milanjiana*, *C. roxburghiana* and *T. triandra* (Skovlin, 1980). Overgrazing and shifting cultivation has resulted in increased bare ground and decreased cover by perennial grasses. Annual grasses and herbs like *Brachiaria leersioides*, *Justicia exigua*, *E. cilianensis*, *Tetrapogon tenellus* and *A. adscensionis* dominate most of the overgrazed areas (Muchoki, 1982).

19. **Nakuru Eco-unit**

This eco-unit covers the Nakuru, Naivasha and Elementaita area where most of the savanna has been turned into wheat farms. Dominant grass in its potential is *T. triandra*, but with increased grazing, *C. dactylon* and *Sida cuneifolia* become dominant. With overgrazing, *H. schimperi* and *Micqsrochloa kunthii* increase or invade. Vegetation cover is changing from grassland to bush through the encroachment of *Tarchonanthus camphoratus* in the Gilgil area.

20. **Narok Eco-unit**

The Loit hills form the southeastern border while Mau escarpment forms the northern border. These two hills attract rain from south and west making the unit wetter than normal. The northeastern part of the plain receives fairly little rain. The *Acacia/Pennisetum* shrubland in the black cotton soil has a mixture of *Pennisetum mezianum*, *C. dactylon*, *Achyropsis greenwayii*, *Justicia elliotii* and *Dychoristes radicans*. *Themeqsda triandra* dominates in red or sandy loam soil (Olang, 1984b). Overgrazing in black cotton soil leads to increase in cover by *J. elliotii* and *D. radicans*. Overgrazing in *Themeda*-dominated areas leads to increase in woody plants such as *Lippia*. spp., *Indigofera* spp., *Justicia exigua* and grasses such as *M. kunthii and H. schimperi*.

21. **Magadi Eco-unit**

From Suswa dam down to the beginning of Lake Magadi is the Kedong valley which has good stands of *Cynodon plectostachyus* and *T. triandra*. The area west of Lake Magadi is dominated by *Sporobolus helvolus* which covers the whole area during the rainy season, but almost all of it is grazed during the dry season.

The area east of Lake Magadi is covered with rock pebbles with scattered *Aristida* spp. during the rainy season, but all of it disappears as the dry season comes. Areas further east and southwards are dominated by *T. triandra*, *C. dactylon*, *P. maximum* and *P. mezianum*.

22. **Tsavo Eco-unit**

The soils are weathered and strongly leached. The area receives rainfall between 400 mm and 600 mm annually. Areas receiving the highest amount of rain are Voi hills and Mtito Andei. Then there is a gradual decrease eastwards.

Vegetation cover and composition also respond to this rainfall pattern. The tree cover is *Acacia/Commiphora* bushland, and grasses around Mtito Andei are dominated by *C. roxburghiana* and *C. ciliaris*. Around Voi are *C. ciliaris* and *Eragrostis superba* while further south around Mackinnon Road are *E. macrostachyus, P. maximum, E. superba*.

Moving eastwards towards the Galana river composition changes and *Chrysopogon plumulosus* and a few *Tetrapogon bidentatus* are present. Further still, *A. mutabilis* becomes dominant during the dry season.

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IDENTIFICATION AND RANKING OF PRODUCTION CONSTRAINTS IN AGROPASTORAL SYSTEMS OF MACHAKOS DISTRICT IN KENYA

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Abstract

The agropastoral systems of southern Machakos District of Kenya are in a semi-arid area with an annual rainfall of 500 mm to 700 mm falling in two seasons. A mean household consists of 15 persons, and owns 20 ha of land, 36 head of cattle, 13 sheep and 45 goats. A variety of crops are grown during the long and short rainy seasons, mainly in mixed stands of maize + pigeon peas, maize + beans, maize + cow peas, and maize + green grams.

Farmers perceive the following as the constraints which limit, in order of their severity, increased production of crops and livestock in their systems: drought, capital scarcity, livestock diseases, crop diseases and pests, poor infrastructure, inadequate extension service, lack of improved inputs, wildlife, land scarcity, labour scarcity, marketing, land tenure, bush encroachment, soil erosion, theft, large family and witchcraft. The ranking of these constraints varies slightly by farm size and survey site. Most farmers view the government as the source of solutions to most constraints. Admittedly many of the constraints would require government action such as improvements in infrastructure and marketing, land tenure, research and extension as pre-requisites for further development.

Researchable constraints of immediate interest to the Kiboko National Range Research Station in order of their importance to farmers are: drought, livestock diseases, crop diseases and pests, and improved crop varieties and livestock breeds.

INTRODUCTION

This paper reports some of the results of a survey conducted by the Socioeconomics Division (SEA) of the Kiboko National Range Research Station (NRRS) to identify and rank production constraints as perceived by the agropastoralists of southern Machakos District of Kenya (Mukhebi *et al.*, 1985).

The Kiboko NRRS has a mandate for conducting research directed at developing technologies for increasing rangeland productivity in Kenya. To make such technologies relevant, production constraints that reflect the felt needs and aspirations of rangeland inhabitants are a pre-requisite.

One of the reasons for the dismal performance of many development projects and programmes is that they are often designed to address problems of target populations as perceived by government officials and other outsiders rather than as perceived by the people themselves. The danger with this approach is that in many cases, considerable amount of resources are expended on trivial problems while priority problems of people are left unattended. The result is often that as soon as external funding and assistance are withdrawn, the initiated development activities which are supposed to be continued by the people are not carried beyond the life of the target group. This happens because sometimes a technical problem is implemented to provide a technical solution, when, in fact, that technical problem ranks low in the minds of the target population. The people may be having a different priority problem on their minds that requires a technical or non-technical solution as a necessary and sufficient pre-condition for any other development activity or project.

METHODOLOGY

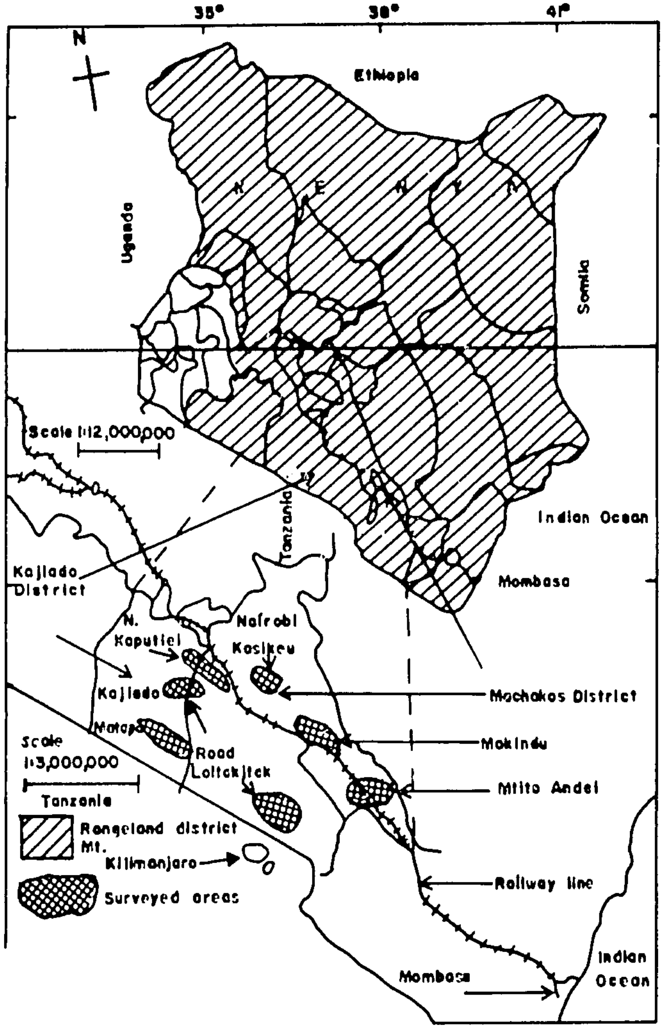
The study was conducted in the southern part of Machakos District stretching from Salama through Makindu to Mtito Andei townships (Figure 1). The area is semi-arid with an annual rainfall of about 500 to 700 mm, falling in two seasons: long rains (March to May) and short rains (September to October). It is inhabited by the Akamba agropastoralists. On average, they own about 20 (±41) ha of land, keep 36 (±56) head of cattle, 13 (±16) sheep and 45 (±48) goats per household of 15 (±13) persons. They grow a variety of food crops during the long and short rainy seasons, mainly in mixed stands of maize + pigeon peas, maize + beans, maize + cowpeas, and maize + green grams.

Three sites were selected for sampling: Kasikeu location near Salama, Makindu location in the middle of the target area and Mtito Andei location at the southern end of the target area. These areas are representative of the mixed farming systems of southern Machakos: relatively intensive systems of Kasikeu, less intensive systems of Makindu and rather extensive systems of Mtito Andei.

On the basis of the above stratification by location, lists of farmers were obtained from area assistant chiefs and agricultural extension officers. (There was no official Land Registry list of farmers as land registration has not been undertaken in the area). A random sample of a pre-determined number of farms was selected from each site. In total, 106 farms were selected: 32 in Kasikeu, 43 in Makindu and 31 in Mtito Andei.

A survey team from SED with the assistance of the extension staff interviewed sampled farmers through single-day visits. The interviews were conducted during May 1985 using a pre-tested questionnaire. Among other variables, respondents were asked an open-ended question: What problems do you consider to be limiting increased production of crops and livestock on your farm? After enumerating all the problems, the respondent was asked how he/she felt they could be solved, one by one.

Figure 1. Surveyed areas in Kajiado and Southern Machakos Districts in Kenya.



RESULTS

Responses regarding felt problems are summarised in Table 1 by farm size and Table 2 by survey site. The problems or constraints to increased crop and livestock production are ranked on the basis of their response frequency.

For all the farms, 17 constraints are identified and ranked in the following order of their severity starting with the most severe: Drought (expressed severally as lack of rainfall, insufficient rainfall, lack of water, crop failure, lack of forage during dry season, etc.); capital scarcity (lack/shortage of cash, loans); livestock diseases; crop diseases and pests; poor infrastructure (lack of or poor roads, hospitals, transport); inadequate extension service (lack of or insufficient skills); lack of improved inputs (lack or unavailability of grade livestock, hybrid seeds, fertilizers, machinery, low yields);

Table 1. Listing and ranking of production constraints by farm size, South Machakos District, Kenya, 1985.

	Farm size						All farm sizes	
	Small (a) (n = 44)		Medium(b) (n = 28)		Large(c) (n = 34)		(n = 106)	
Constraint	%	Rank	%	Rank	%	Rank	%	Rank
Land	23	5	14	9	15	11	18	9
Labour	23	5	7	12	12	12	15	10
Capital	84	2	86	2	74	3	81	2
Extension services	16	8	25	7	32	6	24	6
Improved inputs	18	7	29	6	18	8	21	7
Drought	87	1	93	1	88	2	90	1
Infrastructure	14	9	39	5	32	6	26	5
Soil erosion	5	13	7	12	3	14	5	14
Crop diseases/pests	50	4	46	4	67	4	53	4
Livestock diseases	64	3	57	3	100	1	74	3
Land tenure	9	10	11	10	9	13	9	12
Marketing	9	10	11	10	18	8	10	11
Bush	5	13	4	14	18	8	8	13
Wildlife	9	10	21	8	35	5	21	7
Theft	2	15	4	14	0	-	2	15
Large family	0	-	0	-	3	14	1	16
Witchcraft	0	-	4	14	0	-	1	16

a Small farm size 0 - 9.9 ha.
b Medium farm size 10 - 19.9 ha.
c Large farm size 20 + ha.

wildlife (crop damage by wild animals, livestock predation by wild animals); land scarcity (land shortage, shortage of grazing area; overstocking); labour scarcity (labour shortage, weeding problem, lack of enough time to work on the farm); marketing (lack of or poor markets, low output prices, price fluctuations, delayed payment for marketed crops); land tenure (unsurveyed land, lack of title deeds, trespassing); bush encroachment; soil erosion; theft; large family; and witchcraft.

Farmers' suggested solutions to the above constraints are summarised in Appendices 1-15. The percentage of respondents (n = 106) suggesting solutions to a given constraint is greater than 100 when some respondents suggested more than one solution, and less than 100 when less than 106 respondents suggested any solution. The majority of the respondents view government as the major source of solutions to most constraints.

Table 2. Listing and ranking of production constraints by surveyed area, South Machakos District, Kenya, 1985.

Constraint	Kasikeu (n = 32) %	Kasikeu (n = 32) Rank	Makindu (n = 43) %	Makindu (n = 43) Rank	Mtito Andei (n = 31) %	Mtito Andei (n = 31) Rank	All surveyed (n = 106) %	All surveyed (n = 106) Rank
Land	22	6	21	7	10	12	18	9
Labour	28	5	7	12	13	11	15	10
Capital	91	1	84	3	68	3	81	2
Extension services	9	10	30	5	29	7	24	6
Improved inputs	19	7	14	9	32	6	21	7
Drought	88	2	93	1	87	1	90	1
Infrastructure	19	7	30	5	29	7	26	5
Soil erosion	6	12	5	13	3	14	5	14
Crop diseases/pests	56	3	51	4	52	4	53	4
Livestock diseases	53	4	88	2	74	2	74	3
Land tenure	9	10	5	13	16	9	9	12
Marketing	16	9	2	15	16	9	10	11
Bush	3	14	12	10	10	12	8	13
Wildlife	6	12	21	7	35	5	21	7
Theft	3	15	2	15	0	-	2	15
Large family	3	14	0	-	0	-	1	16
Witchcraft	0	-	0	-	3	14	1	16

DISCUSSION

Among the five severest constraints for all farms, drought is ranked first as expected in this semi-arid area. Capital scarcity is rated second. Many respondents expressed lack of cash for purchasing or hiring farm inputs such as seed or oxen for ploughing. This in turn is reportedly due to low volumes and prices of marketable product surpluses and inaccessibility to commercial credit. Livestock diseases is ranked as the third severest constraint. Respondents attributed this problem largely to inadequate veterinary services, lack of drugs and insufficient livestock dips. Tick-borne diseases such as East Coast Fever and heartwater are reportedly the most prevalent. Crop diseases and pests are the fourth most important constraint in these agropastoral systems. Frequent pests include birds and army worms, the latter coming especially at the on-set of rains following prolonged dry spells. The fifth constraint is poor infrastructure, i.e. lack of roads in many areas, poor roads that are impassable during wet seasons, lack of public transport vehicles, lack of sufficient hospitals and health clinics.

Constraints are identified and ranked by farm size and survey site to determine any differences between farm size and spatial distribution. There is no difference in the list of identified constraints by farm size and site, but there is a slight variation in ranking. While drought is ranked number one constraint in small (0-9.9 ha) and medium (10-19.9 ha) size farms, it is ranked second in the large (20+ ha) size farms, in which livestock diseases are rated as the first constraint.

Smaller farms rely more on crops than livestock for livelihood and vice versa for larger farms. Furthermore, while the farmers of Kasikeu perceive capital as their number one problem (due to more intensive systems), it is ranked number three in Makindu and Mtito Andei locations, where drought is ranked first. Spatial variation in type and ranking of constraints could be expected to become more pronounced with distance. This would call for more caution generalising constraints over large geographical areas.

One striking observation about the suggested solutions is that most respondents view government as the source of solutions to most of their problems. This view is not conducive to development. It encourages people to sit and wait for the government to provide solutions to problems that they themselves can solve or do something about. People ought to be educated "by the government" about the need to find or initiate solutions to constraints facing them by themselves rather than wait for the government to provide the answers. This could be effected through encouragement of community self-help (*harambee*) efforts and through cooperative societies as a few of the respondents suggest for solutions. Admittedly, many of the constraints identified would require government action such as improvements in infrastructure and marketing, land tenure, research and extension as pre-conditions or pre-requisites for any significant development initiated by the people themselves.

Many of the constraints identified are interrelated. Solutions to some may alleviate others. For instance capital is ranked the second constraint considering all farms together. But the capital constraint is related to the land tenure, large family and marketing constraints. For instance, a freehold land tenure system with title deeds would enable farmers to have access to commercial credit by offering the title deeds as security for loans; smaller family size would lessen household consumption expenditure and save cash for purchase of farm inputs; and improved marketing would improve producer prices or increase volume of marketed farm produce, resulting in higher cash in-flow. Each one of these actions would have the tendency of relaxing the household capital constraint.

From the NRRS point of interest, researchable constraints, in order of their priority to the farmers are: drought, livestock diseases, crop diseases and pests, and improved crop varieties and livestock breeds that would be more productive than the current ones. However, the solutions suggested by farmers are important and need to be explored thoroughly before research is designed and undertaken to develop or test technologies that may not contribute significantly to the solution of the constraint in the eyes of the farmers. In fact, researchers would need to gather more detailed field information about these constraints before launching any research, for instance, the magnitude and nature of each constraint. Such information would help in focusing research and developing technologies on more specific aspects of the constraints.

It should be borne in mind that ultimately, whatever solutions (technologies) are devised to address the four and other "researchable" constraints above, farmers will need capital to adopt them. Since capital is ranked the second most severe constraint, it would need to be addressed before farmers would be expected to adopt the new technologies. Furthermore, since the listed constraints are interrelated as already mentioned and their solutions are geared towards the same goal of increasing agricultural production, an interdisciplinary approach in the context of rangeland systems research (RSR) would be the recommended strategy to adopt in addressing the constraints.

CONCLUSIONS

The agropastoralists of southern Machakos District perceive the following as the constraints limiting increased crop and livestock production in their systems, listed from the most to least severe: drought, capital, livestock diseases, crop diseases and pests, infrastructure, extension services, improved inputs, wildlife, land scarcity, labour scarcity, marketing, land tenure, bush encroachment, soil erosion, theft, large family and witchcraft.

The ranking of these constraints varies slightly among different farm size groups and survey sites. The majority of farmers view the government as the major source of solutions to most of the constraints. Admittedly in infrastructure and marketing, land tenure, research and extension services as pre-requisites for any significant development initiated endogenously.

Researchable constraints of immediate interest to the Kiboko National Range Research Station, in order of their importance to farmers are drought, livestock diseases, crop diseases and pests, and improved crop varieties and livestock breeds. More detailed data about these constraints would have to be gathered by researchers in order to focus research on, and develop technologies for more specific aspects of the constraints. As most of the constraints are interrelated and affecting the same goal of increasing agricultural production, an interdisciplinary approach in the context of rangeland systems research would be an appropriate strategy to follow in addressing the constraints.

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APPENDIX

Appendix 1. Farmer-suggested solutions to drought constraint, southern Machakos District, Kenya, 1985.

Solution	% of farmers suggesting (n = 106)
Government to construct new dams and repair old ones	47
Government to construct boreholes	32
Government to assist reforestation and soil conservation	38
Government to implement irrigation project	14
Farmers to feed livestock with hay and supplements	2
Farmers to construct water tanks to store rain water	5
People to organise harambee water project	4
Farmers to practice proper stocking rates	3
Farmers to store food	7
Government to provide seed for drought resistant crops	2
People to practice family planning	1
People to pray to God	8

Appendix 2. Farmer-suggested solutions to capital constraint, southern Machakos District, Kenya, 1985.

Solution	% of farmers suggesting (n = 106)
Government to provide loans	33
Government to increase producer crop prices	6
Government to increase employment opportunities in rural areas	8
Government to issue land title deeds for loan security	7
Government to develop and improve markets for farm produce	2
Government to increase salaries	2
People to form cooperative societies that can provide loans	9

Appendix 3. **Farmer-suggested solutions to livestock disease constraint, southern Machakos District, Kenya, 1985.**

Solution	% of farmers suggesting (n = 106)
Farmers to maintain proper dip strength	4
Government to make drugs more available	14
Government to control stock movement	2
Government to provide more veterinary officers	29
Farmers to dip and spray livestock more frequently	24
Government to research on livestock diseases and drugs	9
Government to construct more dips	32
Government to lower drug prices	2
Government to control tsetse flies	3
Extension officers to visit and advise farmers more frequently	12
Farmers to improve livestock management	2

Appendix 4. **Farmer-suggested solutions to crop diseases and pests constraints, southern Machakos District, Kenya, 1985.**

Solution	% of farmers suggesting (n = 106)
Government to make pesticides more available	19
Government to lower prices of pesticides	14
Farmers to increase use of pesticides	37
Government to research on crop diseases and pests	18
Government to provide more extension officers	18
Extension officers to visit and advise farmers more frequently	19

Appendix 5. **Farmer-suggested solutions to infrastructure constraint, southern Machakos District, Kenya, 1985.**

Solution	% of farmers suggesting (n = 106)
Government to construct more health centres, schools, markets, roads and bridges	25
Government to provide loans for purchasing transport vehicles	15
People to organize harambees for constructing health centres and schools	16
People to buy more public transport vehicles	8
Government to supply more drugs in hospitals	17
Government to educate people more on development	4
Government to provide more doctors	10

Appendix 6. Farmer-suggested solutions to extension services constraint, Southern Machakos District, Kenya, 1985.

Solution	% of farmers suggesting (n = 106)
Government to provide more extension officers	23
Government to provide more transport to extension officers	6
Government to build more farmers' training centres	5
Extension officers to visit and advise farmers more frequently	19
Government to station extension officers near to farmers	10
Government to organise seminars for farmers	5

Appendix 7. Farmer-suggested solutions to improved inputs constraint, southern Machakos District, Kenya, 1985.

Solution	% of farmers suggesting (n = 106)
Government to provide more grade livestock and hybrid crop seeds	20
Government to test soils for fertility	3
Government to provide and distribute fertilizers more timely	18
Government to provide loans for purchase of grade animals	9
Government to make agricultural chemicals more available	7
Government to provide tractors and loans for their purchase	14

Appendix 8. Farmer-suggested solutions to wildlife constraint, southern Machakos District, Kenya, 1985.

Solution	% of farmers suggesting (n = 106)
Government to chase away wild animals	18
Government to kill wild animals	12
Government to compensate farmers for wild animal damage	19
Government to confine all wild animals in game parks and reserves	16
Government to provide loans to farmers for fencing their farms against wild animals	11
Game personnel to patrol more frequently	13

Appendix 9. Farmer-suggested solutions to land constraint, southern Machakos District, Kenya, 1985.

Solution	% of farmers suggesting (n = 106)
Farmers to purchase more land	14
Farmers to preserve livestock forage	8
Government to provide land for settlement	17
Government to provide loans for land purchase	2
People to practice family planning	3
Government to survey and provide individual land title deeds	7
Farmers to intensify production	4
Government to control ants that destroy livestock forage	2

Appendix 10. Farmer-suggested solutions to labour constraint, southern Machakos District, Kenya, 1985.

Solution	% of farmers suggesting (n = 106)
Government to provide loans for hiring labour	13
Government to provide herbicides to minimise hand weeding	4
Government to provide loans for purchasing farm machinery	4
Government to provide loans for hiring oxen	2

Appendix 11. Farmer-suggested solutions to marketing constraints, southern Machakos District, 1985.

Solution	% of farmers suggesting (n = 106)
Government to improve marketing systems for farm produce	5
Government to pay cash for delivered farm produce	2
Government to increase prices of farm produce	4
Government to reduce prices of farm inputs	3
Government to construct auction rings for livestock	1
Farmers to form marketing cooperatives	1
Government to supply weighing scales for cattle	1

Appendix 12. **Farmer-suggested solutions to land tenure constraint, southern Machakos District, Kenya, 1985.**

Solution	% of farmers suggesting (n = 106)
Government to survey land and issue title deeds	9
Farmers to fence their farms	1
Government to provide loans for fencing	2

Appendix 13. **Farmer-suggested solutions to bush constraint, southern Machakos District, Kenya, 1985.**

Solution	% of farmers suggesting (n = 106)
Farmers to clear bush by hand	4
Government to provide chemicals for clearing bush	1
Government to provide loans for clearing bush	3

Appendix 14. **Farmer-suggested solutions to soil erosion constraint in southern Machakos District, Kenya 1985.**

Solution	% of farmers suggesting (n = 106)
Government to instruct and assist farmers to construct terraces and benches	5
Government to carry out reafforestation and reseeding	3

Appendix 15. **Farmer-suggested solutions to soil erosion constraint, southern Machakos District, Kenya, 1985.**

Constraint	Solution	% of farmers suggesting (n = 106)
Theft	Government to increase security	2
	Government to increase employment opportunities	1
Large family	People to practice family planning	1
Witchcraft	Churches to teach religion	1
	Government to arrest witchdoctors	1

RELATIONSHIP BETWEEN PHYTOMASS PRODUCTIVITY, ANIMAL FORAGE PREFERENCE AND ENVIRONMENTAL FACTORS ON SEMI-ARID GRAZED AND UNGRAZED KEY RANGE PLANTS IN TANZANIA

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Abstract

The relationship between phytomass productivity, animal forage preference and environmental factors on semi-arid grazed and ungrazed range plants in Tanzania was investigated from 1979 to 1982, on three range sites at: Pasture Research Centre, Kongwa; Livestock Multiplication Unit, Mabuki, and Livestock Research Centre, West Kilimanjaro. Phytomass production was obtained from nine random quadrats harvested at middle and end of rains. Height-weight relationship from grazed and ungrazed plants coupled with timed observation on grazing animals, and CP content was used to determine animal preference. Phytomass productivity from grazed paddocks ranged from 2.20 to 4.74 tonnes DM ha^{-1} as compared to 2.04 to 3.95 tonnes on ungrazed ones. The combined yield of grasses and browse plants increased phytomass productivity to about 15 tonnes per hectare. There was significant difference (P>0.05) in the utilisation of the key range plants at Kongwa, West Kilimanjaro and Mabuki. Cattle preferred grazing on perennial grasses while goats preferred trees and shrubs. Regression of animal forage preference on phytomass productivity, crude protein and environmental factors, and phytomass productivity on environmental factors for Kongwa and West Kilimanjaro were nonsignificant (P>0.05). To maximise range resources for sustained animal productivity mixed stocking is suggested.

INTRODUCTION

Tanzania has an area under rangeland estimated to be about 60 m ha which supports about 20 million stock units (Anon, 1983). This level of animal production has, however, been below the national nutritional demand (Akilimali, 1983; Chagula, 1983).

Several factors are responsible for the low animal production levels, but the most important of all is shortage of adequate quantity and quality feed in the dry season. This is manifested in overgrazing which is a common feature in all livestock farming systems.

High levels of animal production can, however, be attained from these rangelands provided good range management principles are applied. Practices such as grazing at optimum stocking rate, use of proper grazing management systems and the use of the right kind of animals restore balance between forage supply and animal nutritional requirements.

Grazing animals are known to prefer certain grasses and legumes at some stages of growth, and such behaviour was observed in palatability studies (Johnstone-Wallace and Kennedy, 1944). As a result of selective grazing chemical and botanical composition, herbage consumed by grazing animals differs from the average of the composition of the sward in the field (Johnstone-Wallace and Kennedy, 1944). The amount of green herbage on offer influenced the grazing animal's intake (Johnstone-Wallace and Kennedy, 1944). Similar findings were reported by Chacon and Stobbs (1976), and that intake and total yield of herbage on offer was high and positively correlated.

Cattle also prefer certain plant species at certain stages of growth and various parts of an individual plant (Hafez and Bouissou, 1975). It was further reported that the taste of ingested materials probably provided ultimate basis upon which the animals formed a decision as to whether the material was highly preferred, merely tolerated or completely rejected. On the other hand, the grazing habits of goats was described by Knight (1964), who showed that grass formed the major food preference for East African goats. However, these findings were not in agreement with those obtained by Staples *et al.*, (1942), Jordan (1957), Wilson (1957), Edward (1948), and Lugenja and Kajuni (1979), who concluded that goat diet comprised mainly trees and shrubs.

Although Hancock (1954) found no relationship between temperature and grazing behaviours, Stricklin *et al.* (1976) reported that occurrence of thunderstorms forced animals to stop grazing. Similar observations were reported by Arave and Albright (1981). However, Smith (1959) did not observe any increase in the proportion of the night grazing of individual cattle under high daylight temperature.

In this study attempts have been made to establish the relationship between phytomass productivity (PP), animal forage preference (AFP) and environmental factors (EF) on semi-arid grazed and ungrazed plants in Tanzania.

MATERIALS AND METHODS

A total of 15.4 ha in 14 paddocks, each 105 m x 105 m at Kongwa Pasture Research Centre (PRC), the West Kilimanjaro Livestock Research Centre (LRC) and the Mabuki Livestock Multiplication Unit (LMU) were used for the study. The mean annual rainfall and temperatures were: 250 to 500 mm and 27^{o} to 33^{o}C (PRC, Kongwa), 300 to 400 mm and 20^{o} to 30^{o}C (LRC, West Kilimanjaro) and 700 to 800 mm and 29^{o} to 32^{o}C (LMU, Mabuki). The soils are derived from granite and gneisses at PRC, Kongwa (Owen, 1964); neugene alkaline volcanic materials at LRC, West Kilimanjaro (Anderson and Naveh, 1965) and alluvial lacustrine origin at LMU, Mabuki (Hathout, 1983). In general, all locations are dominated by *Commiphora* and *Acacia* trees, associated with *Aristida, Pennisetum* and *Cynodon* grass species.

Primary productivity (PP) of grasses in tonnes dry matter (DM) was obtained at the middle and end of rains from 1 m^2 quadrats, randomly located in the paddocks. However, PP of trees and shrubs was estimated from twigs of current year's growth of key browse plant within 1.67 metres height. All twigs in predetermined direction were harvested. The bulked-up samples were analysed for crude protein, (CP) calcium (Ca) and phosphorus (P). The grass data were pooled for one season and analysed as split plot by way of ANOVA (Steel and Torrie, 1980). Duncan's multiple range test (DMRT) was used to separate means, and chi-square of independence test was used for chemical analyses data (Sokal and Rohlf, 1969). Tree and shrub yield data were inadequate for statistical analyses.

AFP was determined by recording the time spent by animals on each plant species. Five to ten cows (zebu cattle) and 30-40 goats (blended castrates and females) were used at Kongwa and West Kilimanjaro locations. The species were observed on different dates between 0800-1200 hours at each location and site during the middle and end of rains. Cattle alone were used at LMU, Mabuki. The animals were observed for an hour at all locations, and different species of animals were observed on different days. The percent time spent by cattle and goats grazing on different plant species were summarised under four major plant classifications, namely: annual grasses (*Urochloa trichopus, Aristida adscensionis, Chloris pycnothrix, Chloris virgata, Setaria verticillata, Dactyloctenium aegyptium, Digitaria velutina, Brachiaria deflexa*); perennial grasses (*Bothriochloa insculpta, Chloris gayana, Cenchrus ciliaris, Cynodon dactylon, Pennisetum* spp., *Sporobolus* spp., *Hyparrhenia* spp., *Themeda triandra*); herbaceous plants (*Astripomoea hyosciamoides, Monechma blepharis* spp., *Dalbegia* spp., *Rynchosia sennaarensis, Sida* spp., *Tephrosia* spp.); and trees and shrubs (*Acacia mizera, A. tortilis, Blepharispermum zangubaricum, Bauhinia* spp., *Cadaba* spp., *Combretum* spp., *Euphorbia cuneata, Indigofera* spp.).

Forage utilisation of key range plants (grasses) at Kongwa and West Kilimanjaro was determined from locally compiled height-weight tables as described by Lammasson and Jamson (1942).

Phosphorus, calcium and crude protein were determined using the Molybdenum blue Fiske and Subbarow method, the Oxalate method and the Kjeldahl method respectively. This was in turn used to assess AFP.

Environmental factors (percent relative humidity = % RH, maximum temperatures = Tmax., evaporation = E and rainfall = R) were collected twice daily at 09.00 and 15.00. Percent relative humidity was calculated from standard meteorological tables (Goodchild, 1983).

Regression of AFP (pooled for cattle and goats, grazing animal diet) on PP, AFP on CP, EF on AFP and PP on EF, for Kongwa and West Kilimanjaro locations, were used to establish the relationship between different factors (Sokal and Rohlf, 1969). Data from LMU, Mabuki were too scanty to be included in the regression analyses.

RESULTS

Phytomass Productivity (PP)

Ungrazed paddocks at Kongwa produced 14% more phytomass in tonnes DM ha^{-1} ($P<0.05$) than that which was produced on grazed ones (Table 1a). On the other hand, grazed paddocks at West Kilimanjaro and Mabuki produced 12% more phytomass in tonnes DM ha^{-1} ($P>0.05$) than that which was produced on ungrazed paddocks, respectively (Tables 1b and 1c). Sites 2 and 3 at Kongwa produced significantly more phytomass in tonnes DM ha^{-1} ($P<0.05$) than that produced on site 1. There was no significant difference ($P>0.05$) in the phytomass in tonnes DM ha^{-1} produced on the three sites at West Kilimanjaro. However, site 3 produced 60% and 99% more phytomass in tonnes DM ha^{-1} than that which was produced on sites 1 and 2, respectively (Table 1b).

Table 1a. Mean phytomass productivity in tonnes DM ha^{-1} at Kongwa.

Paddocks	Sites			Mean	
	1	2	3		
Grazed	2.61	3.57	2.97	3.05^{a*}	$\pm$ 0.10
Ungrazed	2.74	3.95	3.75		
Mean	2.68^{a}	3.76^{b}	3.36b	3.48^{b}	
		SE $\pm$ 0.57			

SE = Standard error.
* Means with different superscripts differ significantly at 5% by DMRT.

Table 1b. Mean phytomass productivity in tones DM ha^{-1} at West Kilimanjaro.

Paddocks	Sites			Mean
	1	2	3	
Grazed	2.75	0.89	4.74	2.79^{a}
Ungrazed	1.91	2.89	2.72	2.49a $\pm$ 1.20
Mean		SE $\pm$ 1.01		

SE = Standard error.
* Means with different superscripts differ significantly at 5% by DMRT.

Tree and shrub data from Kongwa location (Table 1d), indicated that high (15.04 tonnes) DM ha^{-1} was produced from site 1. Site 3 was the least productive, with only 0.76 tonnes. *Acacia mizera* produced the highest mean DM (8.52 tonnes) at site 2. The least productive shrub was *Cadaba kirkii*, with mean DM yield of 0.24 tonnes.

Table 1c. Mean phytomass productivity in tonnes DM ha^{-1} at Mabuki.

Paddocks		Sites	
	1	2	3
Grazed	2.59	-	-
Ungrazed	2.04	-	-
Mean	2.32 NS		
SE ±	0.30		

SD = Standard deviation.
Means with different superscripts differ significantly at 5% by DMRT.

Table 1d. Mean phytomass productivity of trees and shrubs in tonnes DM ha^{-1} at Kongwa.

Species		Sites	
	1	2	3
Euphorbia cuneata	1.58	1.70	-
Vittex spp.	1.63	-	-
Grewia spp.	0.60	-	-
Dirichletia pubescens	2.51	-	-
Blepharispermum zangubaricum	8.40	-	-
Acacia tortilis	-	2.56	-
Acacia mizera	-	8.52	-
Cadaba kirkii	0.32	0.24	0.76

Animal Forage Preference (AFB)

Cattle at Kongwa spent 26% more time grazing on perennial grass species than on annual grasses during mid-grains (Table 2a). Least time (14%) was spent on herbaceous plants, and trees and shrubs. A similar trend was observed at the end of the rains (Table 2b). Cattle at West Kilimanjaro spent 66% more time grazing on perennial grasses than they did on annual grasses and herbaceous species (Tables 2c and 2d). However, observations made at Mabuki (Table 2e) indicated that cattle spent 16% more time grazing on perennial grasses than they did on herbaceous plants and annual grasses.

Table 2a. Animal preference (as percent time spent on annual and perennial grasses, and herbaceous plants and trees and shrubs) at Kongwa in January to March 1980, 1981 and 1982.

Plant classification	Sites					
	1		2		3	
	Cattle	Goats	Cattle	Goats	Cattle	Goats
Annual grasses	49	18	21	2	46	2
Perennial grasses	23	21	75	18	46	6
Herbaceous plants	4	21	0	28	4	18
Trees and shrubs	10	30	0	40	0	70

Table 2b. Animal preference (as percent time spent on annual and perennial grasses and herbaceous plants and trees and shrubs) at Kongwa in June to July 1980, 1981 and 1982.

Plant classification	Sites					
	1		2		3	
	Cattle	Goats	Cattle	Goats	Cattle	Goats
Annual grasses	31	8	33	0	29	9
Perennial grasses	36	15	55	29	46	30
Herbaceous plants	17	34	6	23	7	8
Trees and shrubs	5	15	5	48	14	57

Although cattle spent 17% more time grazing on perennial grasses in 1981 than they did in 1982 (Table 2e), there was no significant difference ($P>0.05$) in the way cattle grazed in 1981 and 1982. On the other hand, goats spent 50% of the time browsing on trees and shrubs at Kongwa during mid-rains, and 50% of the time at West Kilimanjaro at the end of the dry season. Least time was spent on grasses as shown in Tables 2a and 2b. Similar trends were observed at the end of the rains (Table 2b).

Table 2c. Animal preference (as percent time spent on annual and perennial grasses, and herbaceous plants and trees and shrubs) at West Kilimanjaro in January to March 1980 and 1981.

Plant classification	Sites 1		2		3	
	Cattle	Goats	Cattle	Goats	Cattle	Goats
Annual grasses	1	1	35	4	8	0
Perennial grasses	99	88	60	26	86	42
Herbaceous plants	0	1	3	0	0	2
Trees and shrubs	0	3	0	40	1	39

Table 2d. Animal preferences (as percent time spent on annual and perennial grasses, herbaceous plants and trees and shrubs) at West Kilimanjaro in October 1982.

Plant classification	Sites 1		2		3	
	Cattle	Goats	Cattle	Goats	Cattle	Goats
Annual grasses	21	4	40	4	17	8
Perennial grasses	71	18	55	18	70	18
Herbaceous plants	0	0	0	0	0	0
Trees and shrubs	1	53	5	51	12	44

Table 2e. Cattle preference (as percent time spent on annual and perennial grasses, herbaceous plants, and trees and shrubs) at Mabuki in July to September.

Plant classification	Year 1981	1982	Mean
Annual grasses	4	14	9
Perennial grasses	57	40	49
Herbaceous plants	35	11	23

Species utilisation: At the West Kilimanjaro location, plant species were 2.27 and 5.67 more utilised than Kongwa and Mabuki locations, respectively (Table 3). However, there was no significant difference (P>0.05) in the way species in the three locations were utilised. *Urochloa trichopus* had the highest (38.3%) utilisation of all the key species at the three locations. *Pennisetum* spp. and *Chloris virgata* followed closely. *Bothriochloa insculpta* was the least (28.05%) utilised species.

Table 3. Mean percent utilisation of key range plants (grasses) for the years 1980-1982.

Species	Locations		
	Kongwa	West Kilimanjaro	Mabuki
Aristida adscensions	28.55	31.40	-
Bothriochloa insculpta	28.05	35.50	-
Cenchrus ciliaris	32.91	30.20	-
Cynodon dactylon	30.63	28.20	-
Chloris virgata	36.25	-	-
Urochloa trichopus	-	38.40	25.75
Pennisetum spp.	-	37.60	30.00

Chemical composition: Analysis of herbage materials, (Table 4a) shows that site 3 at Kongwa had the highest (14.72%) mean percent CP compared to that which was obtained at site 1 (10.75%) and site 2 (9.2%).

Table 4a. Chemical composition (percent, on DM basis) of forage plants in grazed paddocks at Kongwa.

Sites	1981			1982			Mean		
	CP	Ca	P	CP	Ca	P	CP	Ca	P
1	9.28	0.49	0.10	12.22	0.78	0.15	10.75	0.64	0.13
2	13.40	1.42	0.13	5.13	0.34	0.08	9.27	0.88	0.11
3	16.65	1.27	0.20	12.78	0.55	0.12	14.72	0.91	0.16

The highest (11.65%) mean percent CP, at West Kilimanjaro (Table 4b) was obtained from site 1. This was closely followed by site 2 (9.97%) and site 3 (9.38%). There was no pattern in the way Ca and P occurred in the three sites at the three locations. Chi-square of independence indicated that year of grazing had no influence ($P>0.05$) on the chemical composition. However, sites influenced chemical composition at the two locations ($P<0.05$).

Table 4b. Chemical composition percent of DM of pasture plants on grazed paddock at West Kilimanjaro.

Sites	1981			1982			Mean		
	CP	Ca	P	CP	Ca	P	CP	Ca	P
1	17.10	0.62	0.23	6.70	0.54	0.07	11.56	0.56	0.13
2	13.39	0.88	0.17	6.35	0.30	0.06	9.97	0.59	0.12
3	9.38	1.25	0.26	-	-	-	9.38	1.25	0.26

Environmental Factors

Kongwa location experienced high (30.87°C) but less variable (CV = 3.98%) mean temperatures when compared to that at West Kilimanjaro (26.21°C) and Mabuki (30.15°C). However, it was 23.23% and 27.09% more humid at West Kilimanjaro than it was at Kongwa and Mabuki locations respectively. The amount of moisture lost through evaporation ranged from 3.0 to 25.0 mls. West Kilimanjaro received 67% and 16% more precipitation, than that received at Kongwa and Mabuki respectively (Table 5).

Table 5. A summary of environmental factors.

		Relative humidity (%)	Maximum temperature (°C)	Evaporation (mls)	Rainfall (mm)	Wind velocity
Kongwa:	Range	36.00 to 66.00	28.50 to 32.60	3.00 to 6.00	8.60 to 138.80	-
	Mean	32.40	30.90	5.00	67.70	-
	CV	6.03	3.98	23.07	11.01	-
W/Kilimanjaro:	Range	68.00 to 88.00	22.30 to 36.10	4.00 to 24.70	4.70 to 239.00	5.70 to 44.40
	Mean	75.70	26.20	9.90	113.20	98.40
	CV	3.38	7.97	25.81	7.82	11.42
Mabuki:	Range	28.40 to 76.40	29.30 to 31.90	-	7.50 to 196.20	-
	Mean	48.50	30.15	-	78.80	-
	CV	7.87	4.11	-	9.63	-

Regression Analyses

Relationship between AFP and PP, CP, EF and PP and EF are summarised in Table 6.

The results show that T max, R and E were major factors in determining AFP at Kongwa (P>0.05). Phytomass productivity (PP), CP and percent RH were not the major factors determining AFP at that location. On the other hand, PP, CP, T max and R were major determinant factors of AFP (P>0.05), while percent RH and E were less important factors at West Kilimanjaro location.

Table 6. Relationship between AFP and PP, AFP and CP, AFP and EF and PP and EF at Kongwa and West Kilimanjaro locations.

Dependent	Independent	Regression equation	Coefficient of determination (r^2)	Level of significant
AFP	PP	AFP = 21.97+0.55 PP	0.07	NS
AFP	CP	AFP = 21.32+0.20 CP	0.24	NS
AFP	%RH	AFP = 25.18-0.02 %RH	0.03	NS
AFP	Tmax.	AFP = 87.20+3.56 Tmax.	0.79	NS
AFP	R	AFP = 44.55-0.30 R	0.94	NS
AFP	E	AFP = 9.90+3.80 E	0.56	NS
PP	RH	PP = 7.66-0.07 %RH	0.98	NS
PP	Tmax.	PP = 33.09+1.35 Tmax.	0.48	NS
PP	R	PP = 8.31-0.08 R	0.26	NS
PP	E	PP = 6.65-1.00 E	0.18	NS
		West Kilimanjaro		
AFP	PP	AFP = 21.70+0.90 PP	0.77	NS
AFP	CP	AFP = 15.90+0.58 CP	0.77	NS
AFP	%RH	AFP = 15.91+0.08 %RH	0.14	NS
AFP	Tmax.	AFP = 30.72-0.31 Tmax.	0.52	NS
AFP	R	AFP = 20.93+0.02 R	0.98	NS
AFP	E	AFP = 25.47-0.40 E	0.16	NS
PP	RH	PP = 35.26-0.44 %RH	0.67	NS
PP	Tmax.	PP = 12.44+1.35 Tmax.	0.26	NS
PP	R	PP = 1.94+0.01 R	0.08	NS
PP	E	PP = 14.68+1.99 E	0.66	NS

NS = non significant at $P<0.05$.

DISCUSSION

Phytomass Productivity (PP)

At Kongwa ungrazed paddocks produced 14% more mean PP in tonnes DM ha^{-1} than grazed paddocks, in contrast to Mabuki and West Kilimanjaro locations (Tables 1a, b, and c). The relatively low mean PP produced on grazed paddocks at the two locations were probably due to less grazing effect. The high phytomass produced on ungrazed paddocks at Kongwa is comparable to that obtained by Pearson (1965) who reported that grazed areas produced about 1.78 tonnes DM ha^{-1} annual top growth when compared to protected areas (1.99 tonnes DM ha^{-1}). The low mean PP obtained on ungrazed paddocks at Mabuki and West Kilimanjaro locations might be due to low moisture infiltration rates resulting from soil surface crusting. The high mean PP produced by *A. mizera* (8.52 tonnes) and *B. zangubaricum* (8.40 tonnes) shown in Table 1d is probably due to the growth habit of the shrubs. *A. mizera* tends to branch about a metre from the surface of the soil and these branches usually terminate into productive branchlets within browsing height. *B. zangubaricum* tends to sprout profusely at the base, forming large clumps, with abundant forage within browsing height. On the other hand *E. cuneata, Vittex* spp., *Grewia* spp., *D. pubescens*, and *C. kirkii* are either single-stemmed, or branch high up, thereby contributing less to grazing.

Animal Forage Preference (AFP)

The high preference for annual and perennial grasses by cattle, and herbaceous plants and trees and shrubs by goats, observed at Kongwa, West Kilimanjaro and Mabuki (Table 2) confirm those of Staples *et al.* (1942), Edward (1948), Jordan (1957), Wilson (1957), and Lugenja and Kajuni (1979). In New South Wales, goats were observed to eat *Acacia aneura* and *Cabtis* spp., while cattle had a high preference for *Calotis* spp. and *Chenopodium anidiphylum* (Squires, 1982). The highest preference for perennial grasses exhibited by cattle (99%) on site 1 at West Kilimanjaro (Table 2c) was probably due to high percent CP content in the grazing (Table 4), which was mainly made up of *Cynodon* and *Bothriochloa* spp. This trend was, however, not observed on other sites and locations. In a study of cattle browsing behaviour in semi-arid area of Tanganyika, Payne (1963) observed that nutritive value and succulence determined the species that were browsed. The highest preference for perennial grasses exhibited by goats (88%) (Table 2c) was possibly due to the absence of trees and shrubs with forage within browsing height.

Utilisation

The highest mean percent utilisation (33.55%) observed at West Kilimanjaro is probably due to common use in practice at the location. The non-significant differences in the utilisation of key range plants at the three locations suggest that the experimental animals had probably low grazing action.

Environmental Factors (EF)

The high mean maximum temperature (30.9^{o}C) observed at Kongwa location, relative to those at West Kilimanjaro and Mabuki (Table 5), suggest that the location experienced more adverse conditions for plant growth than either West Kilimanjaro or Mabuki. The high coefficient of variation (25.81%) observed at West Kilimanjaro suggest that the location was probably influenced by the mountain's effect. On the other hand, the high percent relative humidity observed at West Kilimanjaro was probably due to high precipitation coupled by low temperatures (Table 5). The high wind velocities (98.4 km/hour) were probably responsible for the high moisture (99.0 mls) lost through evaporation whereas, the high amount of precipitation received probably suggests that the experimental period fell in more than average rainfall years.

Regression Analyses

The variation in AFP associated with differences in PP and CP at West Kilimanjaro ($r^2 = 0.77$) is probably due to decrease in leaf availability as grazing progressed in the season. Between January and March pastures at West Kilimanjaro and Kongwa are usually mature and dry and although the animals graze selectively, the choice at West Kilimanjaro is limited by the abundancy of less palatable species of *Pennisetum*. These observations are similar to those by Chacon and Stobbs (1976) working with cattle in Australia. The authors showed that the number of bites and intake declined when leaf decreased. They attributed these observations to lack of desire by ruminants to harvest feed, to nitrogen or mineral deficiencies, or to bulk in the rumen thus preventing the development of an eating drive.

The variation in AFP associated with differences in T max (r^2 = 0.79) and rainfall R(r^2 = 0.94) for Kongwa and T max (r^2 = 0.52) and rainfall (r^2 = 0.98) for West Kilimanjaro, is probably due to favourable influence of high ambient temperatures and rainfall they have on PP (Table 6). However, these factors tend to decrease CP and subsequently digestibility (Deinum and van Soest, 1968). The low AFP might also be due to rumen pH depression associated with high ambient temperature and humidity (Mishra *et al.*, 1970).

The high, but non-significant effect of T max on AFP (Tables 5 and 6) is probably due to inherent differences in the herds used in the study at Kongwa and West Kilimanjaro locations. The herd at Kongwa seems to have been more adapted to temperature conditions than that at West Kilimanjaro. There was no pattern in the way R and E affected AFP and PP at the two locations. However, percent relative humidity seem to have been negatively correlated with PP at these locations. The high but non-significant negative relationship between AFP and R at Kongwa probably suggests the detrimental effect of non-effective precipitation on grazing animals under semi-arid conditions. Non-effective precipitation encourages termite activity, resulting in low standing matter (Lugenja and Kajuni, 1979).

The high but non-significant positive relationship between AFP and E at Kongwa and West Kilimanjaro is probably due to conducive environmental conditions experienced as a result of evaporation. The two locations are characterised by high wind velocities which probably bring about cooling effect to grazing animals. On the other hand, the non-significant positive relationship between PP and E at the two locations, is in agreement with the established fact that DM production depends on the amount of moisture lost through evaporation and transpiration processes (Lane, 1976).

CONCLUSION

The results show that the mean PP in tonnes DM ha^{-1} of the range increased from 4 to 15 tonnes DM ha^{-1}, when grasses and browse plant productivity is taken into consideration. The results also show that cattle grazed mainly on grasses while goats grazed mainly on herbaceous plants, trees and shrubs in this trial at Kongwa and West Kilimanjaro. The results further show that cattle and goats grazed grasses and browse plants to some degree, suggesting that there is a dietary overlap between the two animal species. These observations imply that for better and uniform range utilisation, cattle and goats should be mixed during grazing periods. In future intensive studies on stocking rate will be carried out for the different ecological zones in order to achieve optimum multiple range use, and identification of the major browse plants and establishing their roles in ruminant nutrition will be done.

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GRAZING BEHAVIOUR OF MAASAI CATTLE

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Abstract

The grazing behaviour of Maasai cattle was influenced by season, area and grazing orbit. In a grazing day the cattle spent 1, 8, 14, 15 and 62% of their time drinking, ruminating, resting, walking and grazing respectively. The mean length of the grazing day of Maasai cattle is defined, as from the time they left their bomas in the morning until they returned for the night; this duration was 10.8 ± 0.6 and 10.4 ± 0.6 hours for cattle and calves respectively. The mean grazing orbit was 15.5 and 10.8 km for adult cattle and calves respectively. A vibracorder proved quite accurate in timing cattle activities.

INTRODUCTION

Daily intake of grazing cattle is determined by the product of time spent grazing, the rate of biting and forage intake per bite (Hodgson, 1982). It therefore follows that grazing time influences intake directly, while other grazing habits such as drinking, ruminating, playing and resting may influence intake either positively or negatively. In Africa pastoral herdsmen exercise a major influence on the grazing behaviour of their cattle through herding. By herding, man decides when and where cattle are to go for grazing. So the skill of a herdsman coupled with environmental factors are the determinants of a successful grazing day in terms of forage intake.

The endeavour to understand the grazing behaviour of the Maasai cattle was part of a study of the Maasai pastoral production system. This study was initiated by the International Livestock Centre for Africa (ILCA). The study was carried out in three group ranches which were selected on the bases of their ecology and development gradients in Kajiado District, Kenya.

MATERIALS AND METHODS

The five-minute method was used to study grazing behaviour, as suggested by Hancock (1953) and used by Lampkin *et al.* (1958) at Muguga, Kenya. At the end of each five-minute period, an observation was made and the behaviour of each selected animal recorded. Behaviour activities recorded were: species of grass or browse grazed, resting while either standing or lying, ruminating while standing or lying, walking and drinking. With the exception of the species grazed the other behaviour patterns were confirmed if they continued for ten or more seconds.

In theory, a total of 144 observations could be made from 7.05 to 19.05 hours which is the normal daylight period in Kenya at this latitude. However, the grazing period does not always extend over the entire daylight period, but rather is modified according to the schedule and needs of the individual livestock owner. In each herd, three animals were selected according to the role each cow appeared to play in the herd: the herd leader, an ordinary cow and a laggard. Each animal selected was followed by one observer during the entire grazing day.

The observers used pedometers to monitor the distance covered during each grazing day. At the end of each day the distance walked was taken as the average of the three pedometers used. Pedometers were calibrated regularly against a known distance. A vibracorder was used as described by Stobbs (1970) to monitor total time spent actively, in grazing, walking, drinking and ruminating. For statistical analysis, SPSS and least squares procedures of Harvey (1977) were used.

RESULTS

Grazing Day Length

The mean length of the grazing day of Maasai cattle, defined as from the time they left their bomas in the morning until they returned for the night, was 10.8 ± 0.6 and 10.4 ± 0.6 hours for adult cattle and calves respectively. The difference between the adults and the calves of 0.4 hour was not significant ($P>0.05$).

Although the 28 grazing days recorded by the five-minute method and the vibracorder did not overlap entirely, the latter also recorded an average of 10.6 ± 0.8 hours. During green seasons grazing days were longer than during dry ones; the averages for the green and the dry were 11.1 ± 0.4 and 10.3 ± 0.8 hours respectively but the difference was not significant ($P > 0.05$). The measurements of the grazing day with an ordinary watch and the vibracorder were very similar and the differences between them were within the experimental error. A vibracorder had the advantage over human observers that, once the instrument was set with a chart covering seven days' records, it needed no further handling until the expiry of the seven days. The vibracorder also recorded night activities between 18.30 to 07.30 hours. The average duration of night activity for the green and dry seasons was 2.0 ± 1.3 hours and the seasonal difference was not significant ($P>0.05$). The night activity was assumed to be mainly rumination. Total time spent ruminating on the average was 2.8 hours divided into 2 hours at night and 0.8 hours during the day.

Distance Walked per Grazing Day

The mean distance walked per grazing orbit was 15.5 ± 5.0 and 10.8 ± 4.8 km for adult cattle and calves respectively. Hence adult cattle walked 4.7 km more than calves. The difference was 36% of the overall mean and significant ($P<0.05$). This difference in walking distance between the calves and the adult cattle was due to grazing management. Calves grazed in reserved areas near the homestead (Olopololi), while the adults utilised the communal grazing areas. Calves had more opportunity for high intake since in the homestead herbage was relatively more abundant than in the communal areas, necessitating less walking in search of forage. For the adult cattle the distance walked was dependent on the herder's skills, on the grazing orbit followed, and whether it was a watering day or not.

Specific Grazing Habits

The overall percentage time spent in a grazing day in specific activities were 1, 8, 14, 15 and 62% in drinking, ruminating, resting, walking and grazing respectively. The percentage time spent was different between seasons, areas and grazing orbits and there were significant interactions of season x area and season x grazing orbit.

Seasonal effects were highly significant ($P<0.01$) while animal type was not ($P>0.05$) for any of the activities. The coefficient of variations of the activities were large, and they ranged from 23 to 98.

Table 1 presents various activities as affected by seasonal changes. More time was spent drinking in the green than in the dry and the dry/green seasons. Cattle ruminated less in the green than in the other two seasons, while rumination time during the day was 8% longer in the dry than in the green season. Cattle rested 13% of the day longer in the dry than in the green or dry/green seasons, but they walked for a longer period in the green and dry/green than dry season. Proportion of time spent on grazing was longest in the green season (66%), followed by dry/green (62%) and 57% for the dry season.

Ratios between rumination and grazing time were 1:8, 1:9, 1:17 and 1:5 for the overall mean, dry/green, green and dry respectively. Although this calculation of the rumination to grazing time ratio was only for the day-light period when viewed together with Table 1, a trend emerged linked to forage quantity and intake. Grazing and ruminating times appeared to be

Table 1. Percentage of grazing day spent on different activities by season.

Season	N	Drinking	Ruminating	Resting	Walking	Grazing
Overall mean	61	1 (6) (0.1)	8 (48) (0.8)	14 (84) (1.4)	15 (90) (1.5)	62 (372) (6.1)
Dry/green Feb/Mar 1983	21	1^{b} (6) (0.1)	7^{a} (42) (0.7)	13^{a} (78) (1.3)	17^{a} (102) (1.7)	62^{ab} (372) (6.2)
Green May/June 1983	28	3^{a} (18) (0.3)	4^{c} (24) (0.4)	8^{b} (48) (0.8)	19^{a} (114) (1.9)	66^{a} (396) (6.6)
Dry Sept/Oct 1983	12	1^{b} (6) (0.1)	12^{b} (72) (1.2)	21^{c} (126) (2.1)	9 (54) (0.9)	57 (342) (5.7)

abc Except for the overall means other means having no superscript letter in common differ at the $P\leq0.05$.
(In brackets = time in hours).

interrelated; low quality forage in the dry season resulted in longer ruminating and shorter grazing (intake) time, while the reverse was found in the better conditions of the green season. It is accepted that intake is limited by forage quality. But in this production system it appeared that rumination time was negatively related to intake.

DISCUSSION

That the vibracorder can be used successfully to record grazing time (Stobbs, 1970) was confirmed in this present study. It has many obvious logistics advantages over observers with watches. It is a tool that could be used to compare herdsmen and their herds. The vibracorder was also effective in recording time spent on rumination during the night. Therefore the total ruminating time was calculated by adding the night time recorded by the vibracorder to that of the day time recorded by observers. The total ruminating time in 24 hours of 2.8 hours fell at the lower end of the range of 2.5 to 10.4 hours, reported by Harker *et al* (1953) and van Soest (1982).

Maasai cattle walked shorter distances than pastoral Fulani cattle in northern Nigeria studied by van Raay and de Leeuw (1974) who recorded daily averages ranging from 16 to 30 km. Maasai cattle walked less because of better grazing resources due to the bimodal rainfall and a greater degree of sedentarisation and a closer spacing of water sources, all leading to a lesser need for walking.

The percentage time spent grazing of 62% or 6.7 hours was intermediate between times reported for herded cattle (65 to 89%, Semenye 1981; Otchere, 1986) and non-herded cattle (55%, Harker *et al.*, 1953; Lampkin *et al.*, 1958; Lampkin and Quarterman, 1962).

Lack of significant difference between animal types within a single herd means that the behaviours for the three different categories were similar. In a situation where cattle are not herded, similarity between the categories is less likely. Where cattle are herded the influence of the herder dominated the individual expression of cattle. However, when it came to behaviour on which the herder had less influence such as rumination, significant differences between grazing areas were observed due to differences in forage quality and water availability. Rumination time is known to vary with the forage quality (Hancock, 1953; van Soest, 1982), which varied across areas and seasons.

More time was spent drinking in the green season, when there was plenty of surface water. Reasons have been advanced above for expecting longer rumination periods in the dry season when forage was at its lowest quality. Since they had access to forage of high quality and plenty of water in the green season, cattle should enjoy more resting time instead of less. However, it is possible that more resting occurred in the dry/green and dry seasons than in the green because of higher prevailing temperatures and the desire of either the cattle or the herder to avoid unnecessary effort. With increasing temperature, cattle

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THE ROLE OF BODY WEIGHT CHANGES AND OTHER FACTORS IN THE CONTROL OF FERTILITY OF BEEF CATTLE AT ATHI RIVER RANCH, KENYA

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Abstract

A study of breed and environmental factors affecting calving interval of range-fed beef cattle was conducted at Athi River Ranch in the Kenyan rangelands. In experiment 1, conception period, rainfall and body weight changes prior to conception were evaluated from a total of 308 calving intervals. In experiment 2, 1985 in-calf females were supplemented during the dry season in 1978, 1979 and 1980. In experiment 3, 122 cows were allowed to wean their calves at various ages at the end of September, October and November/December in 1977, 1978 and 1979.

Short mean calving intervals were associated with conception between November and January. Increased rainfall during the month prior to conception was correlated with a linear and highly significant ($P<0.01$) reduction in calving interval depending on conception period. Year effects were highly significant ($P<0.005$). The target joining weight was around 318 kg. Above the target weight, fertility became a function of the absolute body weight such that heavier cows at joining were more fertile ($P<0.01$) than lighter ones. Below the target weight, fertility was associated with females that gained weight or suffered less body weight loss during the month prior to conception. Previously, dry cows tended to gain weight prior to conception to the detriment of fertility ($P<0.005$). Effect of calving month was highly significant ($P<0.005$) depending on age of breeding females. Influence of dry season supplementation was significant but was modified by a number of factors such as age, year and previous parity. There was no significant difference in fertility of cows that were supplemented with energy or energy plus urea before calving. Generally, cows that were supplemented after calving had a shorter mean calving interval. Effects of weaning period, month and year were marginally significant ($P<0.05$). Fertility improved as the dam's age increased from three years onwards but declined after about nine to ten years. Effects of previous parity and breed were marginal ($P<0.05$) depending on conception period. With supplementation, Boran crosses had a significantly ($P<0.01$) shorter mean calving interval than the pure Boran females. In general, effects of breed were minor compared to environmental factors especially those associated with conception period.

INTRODUCTION

More than 50% of the 8.7 million beef cattle in Kenya are reared in semi-arid to arid areas or rangelands (Livestock Development Division, 1983). The overall offtake of beef is not adequate to meet domestic demand and at the same time sustain an export market. There is need, therefore, to increase not only efficiency of production but also to multiply the beef population quickly. The latter objective calls for a higher level of fertility. Not only does low fertility reduce productivity but it also limits improvement of the herd genetically. For instance, when calving rate is low, nearly all replacement heifers must be used to maintain the herd numbers, and this curtails selection intensity thereby lowering the rate of genetic improvement. Besides, a decline in fertility would result in a compensatory increase in the number of unproductive and aged cows with adverse consequences of overstocking leading to environmental degradation which is often irreversible.

Fertility can be evaluated in terms of calving rate, i.e. the number of calves born in relation to the number of breeding females exposed to the bulls per annum. This measurement is ideal for survey studies. For selection purposes, individual cow data are required for which the parameter evaluated is the calving interval, i.e. the period between two successive parturitions. Although several factors may influence fertility, there is overwhelming evidence that inadequate nutrition is the most important single factor mitigating reproductive efficiency in beef cattle (Topps, 1977). This observation is particularly relevant to tropical rangelands where pronounced seasonal changes in rainfall (French, 1957) contribute to a very precarious feed supply. Topps (1977) has associated seasonal changes in feed supply with corresponding changes in body weight of grazing beef cattle with adverse consequences on reproductive performance. The objective of this study was to characterise the influence of body weight changes and related factors that are associated directly or indirectly with the nutritional status of beef cows grazing natural pasture on calving interval.

MATERIALS AND METHODS

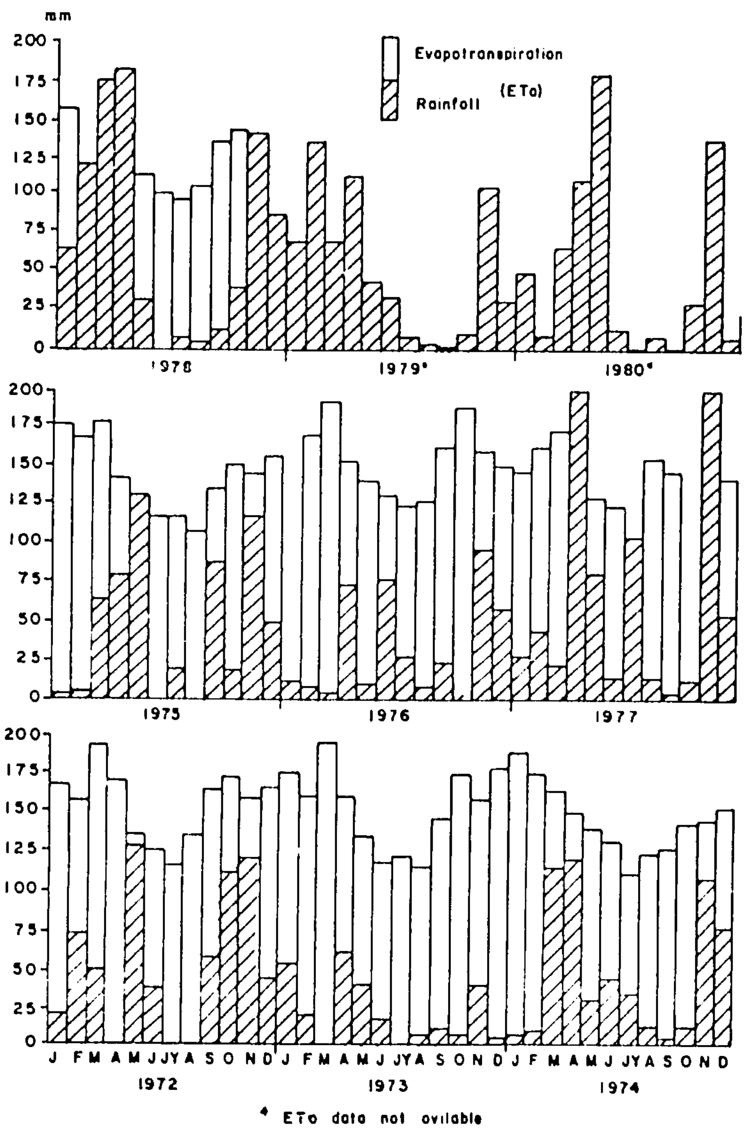
Site

The study was conducted at KARI's field station near Athi River. The ranch lies in a semi-arid zone with a bimodally distributed rainfall averaging 565 mm per year (Figure 1). The main grass species is *Themeda triandra* Forsk on gently undulating mosaic of ridges and shallow valleys of black clay loams (Gethin-Jones and Scott, 1955; Ledger *et al.*, 1969).

Breeding Females

The genotypes were the Boran, small East African Shorthorn Zebu (EASZ) and their F_1 progeny from Hereford bulls. All animals were run as one herd and were grazed on natural pasture. Routine measures to control ticks and vaccinations against foot-and-mouth, contagious abortion, rinderpest, blackquarter and anthrax were undertaken. Random mating was followed throughout 1973. From 1974 until 1976, mating was confined between June and August, but this was subsequently brought forward between May and July. Heifers were first mated after attaining a liveweight of 250 kg.

Figure 1. Rainfall and evapotranspiration (mm) at Athi River Ranch.



Experiment 1: Evaluation of Breed and Environmental Factors Affecting Calving Interval

Conception Period

Each calendar year was divided into six two-month periods to coincide as much as possible with the seasonal pattern of rainfall and temperature. Date of "second" conception was estimated from date of calving and assuming a mean gestation period of 283 days (Hutchison and Macfarlane, 1958). An appropriate conception period was then assigned to each calving interval.

Soil Moisture Index

Evaporative loss (E_o) was estimated using McCulloch's (1965) Tables from data collected at the meteorological site at the ranch. E_o values were multiplied by a crop coefficient of 0.86 derived by Pereira and McCulloch (1962) to predict evapotranspiration (ET_o) from a vegetative cover. A soil moisture index (SMI) was calculated from the equation:

$$SMI = \frac{\text{Total monthly rainfall (mm)}}{\text{Estimated } ET_o \text{ (mm/month)}}$$

which, for the purposes of this study, gave an indication of soil water adequacy for pasture growth after taking into account the biggest water loss (ET_o). Indices were calculated for each calving interval for the period of one month (SMI1) and one to two months (SMI2) prior to "second" conception.

Grouping of Females

Arising from variation in the breeding season, females were divided into five groups depending on the period taken after "first" calving before joining with the bulls. Group 1, regarded as the normal class, had bulls within 60 days post-calving. In groups 2, 3 and 4, joining took place between 61-150, 151-230 and 231 or more days after calving respectively. In group 5, females did not conceive during the "first" breeding season but did so during the subsequent mating period. Preliminary analysis indicated that there was no additional information lost by excluding groups 3 and 5. Consequently, only groups 1, 2 and 4 were retained for final evaluation.

Experiment 2: Effect of Strategic Supplementation on Calving Interval

Three experimental rations were prepared for supplementing in-calf cows during the dry period between January and March in 1978, 1979 and 1980 as follows:

Ration A: 2 kg chopped fresh grass from the paddocks.
Ration B: 2 kg ground sorghum grain (*Sorghum vulgare*) mixed with 500 g of sugarcane molasses (Energy).
Ration C: 2 kg ground sorghum grain mixed with 500 g molasses and 75 g of urea (Energy + Nitrogen).

The supplemented regimes were:

(i) chopped grass (control) - Ration A

(ii) pre-parturient supplementation

(a) Energy alone - Ration B

(b) Energy + Nitrogen - Ration C

(iii) Post-parturient supplementation - Ration 3.

Cows on feeding regime (i) and (ii) were supplemented during the last two months of pregnancy for varying periods until they calved down while those on regime (iii) were supplemented up to 60 days.

Experiment 3: Effect of Weaning on Calving Interval

Breeding females were suckling their calves each year. The calves were weaned in three batches at the end of September, October and November/December during 1977, 1978 and 1979 when they were between 5 and 9 1/2 months old.

Data

Each female was regarded as an entity during the breeding season and data were compiled to include breed, birth and calving dates, previous parous state i.e. whether the animal was a heifer, dry cow or suckling a calf at conception prior to the calving interval in question and conception period. The covariables included body weight at weaning (WWN), "earlier" calving (WCV), one month after calving (W1ACV), one and two months prior to "second" conception (W1BC and W2BC respectively) and at "second" conception (WCP), SMI1 and SMI2. From this information, age at "earlier" calving, calving interval and weight changes WWN-WCV, W1ACV-WCP, W1BC-W2BC and W1BC-WCP were computed. Factorial effects in experiments 1, 2 and 3 are summarised in Tables 1, 2 and 3 respectively.

Table 1. Data structure and number of females in experiment 1.

Class	Levels	Groups 1	2	4	Total
1. Breed type	Boran	44	29	58	131
	EASZ	42	47	33	122
	Crosses*	28	20	7	55
2. Dam's age at earlier calving (years)	3 or below	18	16	22	56
	4-8	65	38	71	174
	9 and above	31	42	5	78
3. "Second" conception period	Mid Jan-mid March	1	7	33	41
	Mid March-mid May	2	-	8	10
	Mid May-mid July	52	59	19	130
	Mid July-mid Sept	37	26	1	64
	Mid Sept-mid Nov	6	-	-	6
	Mid Nov-mid Jan	16	4	37	57
4. Year of "second" conception	1973 (early)	2	11	70	83
	1973 (late)	26	-	3	29
	1974	2	3	-	5
	1975	28	59	19	106
	1976	23	23	-	46
	1977	33	-	6	39
5. Dam's previous parity	Heifer	17	17	31	65
	Dry cow	39	14	49	102
	Suckled	58	65	18	141
Total		114	96	98	308

*Crosses were F_1 from Boran and EASZ cows x Hereford bulls.

Table 2. Data structure and number of females in experiment 2.

Class	Levels	No. of observations
1. Breed type	Boran	34
	Boran x Hereford (F_1)	52
	EASZ	48
	EASZ x Hereford (F_1)	51
2. Dam's age at earlier calving (yrs)	4	22
	5-9	100
	10 and above	63
3. Dam's previous parous state	Dry cow	72
	Suckled	113
4. Feeding regime	Chopped fresh grass	40
	Pre-parturient supplementation	57
	(a) Energy	43
	(b) Energy + Nitrogen	45
	Post-parturient supplementation	57
5. Month of earlier calving	February	83
	March	58
	April/May	44
6. Year of earlier calving	1978	58
	1979	53
	1980	74
Total		185

Table 3. Data structure and number of females in experiment 3.

Class	Levels	No. of observations
1. Breed type	Boran	21
	Boran x Hereford (F_1)	42
	EASZ	29
	EASZ x Hereford (F_1)	30
2. Dam's age at weaning (yrs)	4	14
	5-9	70
	10 and above	38
3. Weaning month	End of September	35
	End of October	38
	End of Nov/December	49
4. Weaning year	1977	28
	1978	43
	1979	51
5. Calving month*	Jan/February	46
	March	36
	April/May	40
Total		122

*Month of calving following weaning in question.

Statistical Analysis

The sources of variance and covariance for calving interval were analysed using the generalised least-squares regression methods for multiple classifications and non-orthogonal data as described by Harvey (1960) and adapted by Siebeck (1976) in his computer programme, SYSNOVA. All effects were considered fixed. The estimate of the mean squares attributable to any effect was computed after all other effects in the evaluation model had been fitted and was tested against that of the residual.

The generalised model used was:

$$Y_{ijkl} = \quad + a_i + b_j + c_{jk} + (ab)_{ij} + (ad)_i + d(D_{ijkl}-D) + e_{ijkl}$$

where,

Y_{ijkl} = calving interval of an individual cow

= effect common to all cows

a_i = effect of the ith A class after removal of

b_j = effect of the jth B class after removal of

c_{jk} = effect of the kth C class within the jth B class after removal of the jth B class. This was hierarchical effect of nutrients within the pre-parturient feeding regime.

$(ab)_{ij}$ = effect of the ijth AB sub-class after the average effects of A and B have been removed.

$(ad)_i$ = effect of an interaction between A and the continuous variate D_{ijkl}. This interaction between a treatment and a covariate enables particular slopes to be fitted.

d = partial regression coefficient of calving interval Y_{ijkl} on D_{ijkl}.

e_{ijkl} = random errors.

RESULTS

Weight Change During the Month Prior to "Second" Conception

The effect of weight change on calving interval was influenced significantly (P<0.01) by the period during which females reconceived and is depicted in Figure 2. During the May-July period, animals reconceived at an average weight of 331 kg, and weight changes did not affect calving interval to any appreciable degree. Weight gains up to 10 kg prior to conception between July and September were associated with short calving intervals (Figure 2). Females reconceived between September and January at an average weight of 308 kg, and long intervals were associated with weight loss in excess of 10-15 kg. Influence of weight change also varied significantly (P<0.005) and curvilinearly depending on year of "second" conception as shown in Figure 3. While weight gain during 1976 resulted in systematic and sharp reduction in calving intervals, this effect was marginal during 1975. Weight gain during 1973/74 caused considerable variation in calving interval.

Weight Change Between One to Two Months Prior to "Second" Conception

The effect of this parameter was linear and highly seasonal (P<0.005) and is depicted in Figure 4. Females that gained weight prior to conception between July and September had calving intervals which were reduced by 0.7 days for each kg increase in body weight. This trend was reversed in the case of animals that conceived during periods other than July-September such that females that gained weight also had longer calving intervals. However, effect of weight gain prior to conception between May and July was marginal.

Figure 2. Relationship between calving interval and weight (W1BC-WCP) within conception period of group 1 cows.

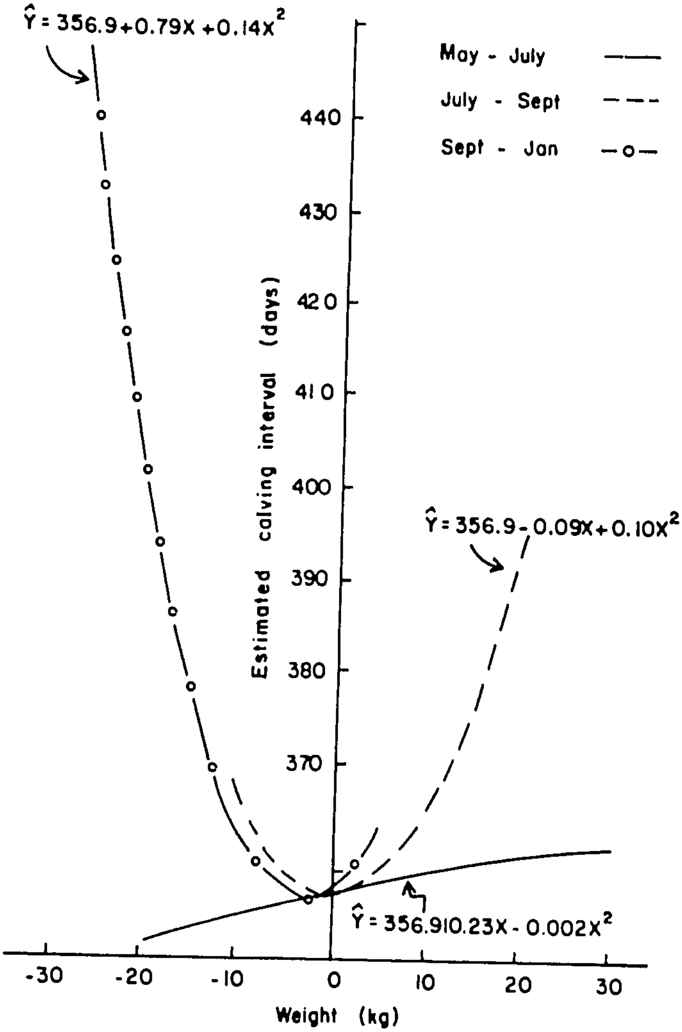


Figure 3. Relationship between calving interval and weight (W1BC-WCP) within conception year of group 2 cows.

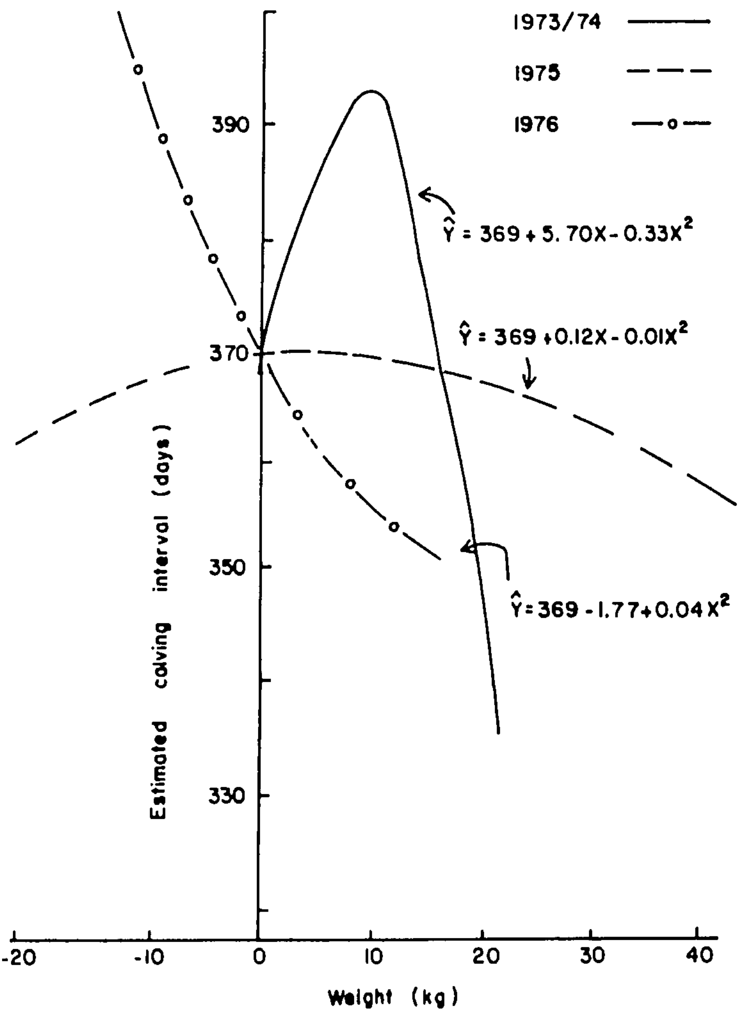
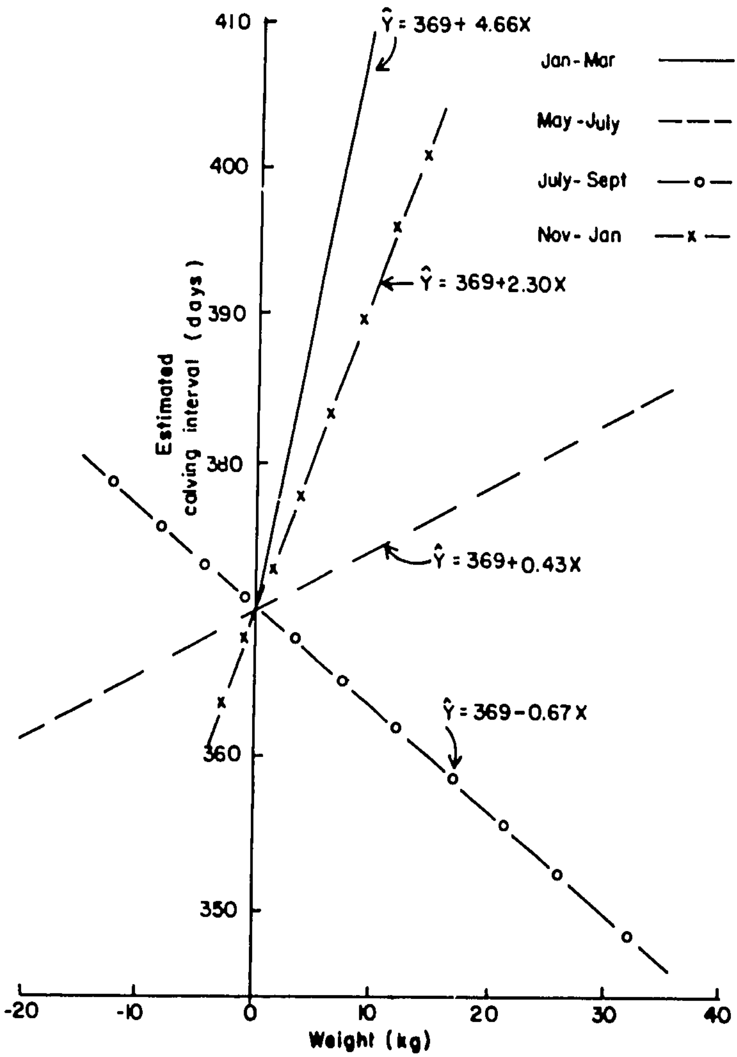


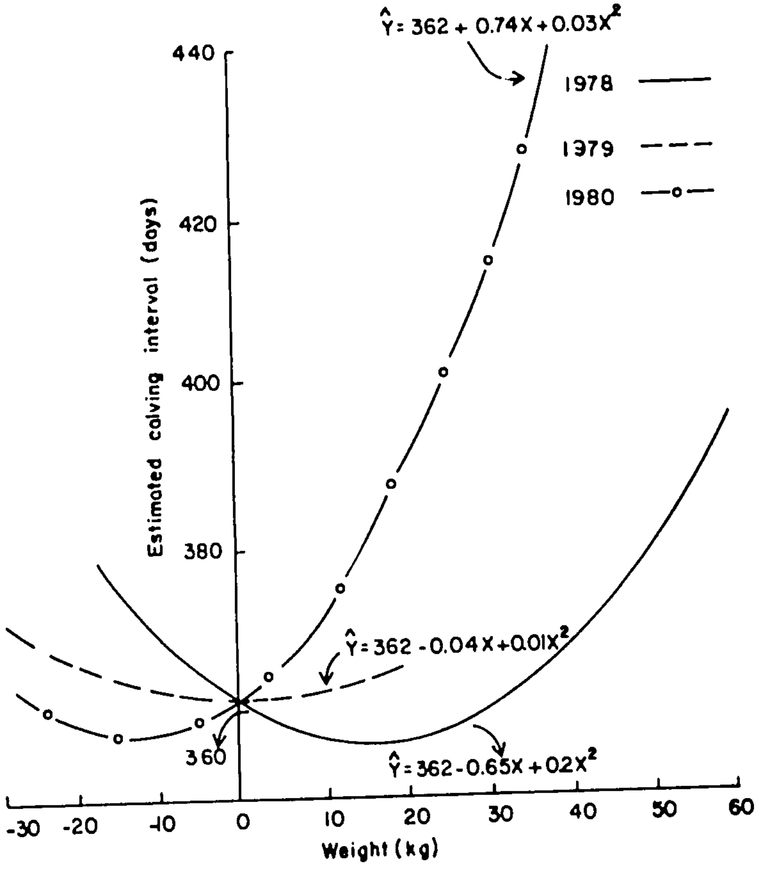
Figure 4. Relationship between calving interval and weight (W1CP-W2CP) within conception period of group 2 females.



Weight Change Between One Month After Calving and Reconception

Influence of this factor varied significantly (P<0.05) depending on the year when reconception occurred as depicted in Figure 5. During 1978, weight gains up to 25 kg were associated with short calving intervals. During 1979, effect of weight change was marginal. Weight gains during 1980 resulted in long intervals. Mean calving interval was reduced by 0.7 days for each kg increase in body weight following calving during March; otherwise the overall effect of weight change did not vary across calving month.

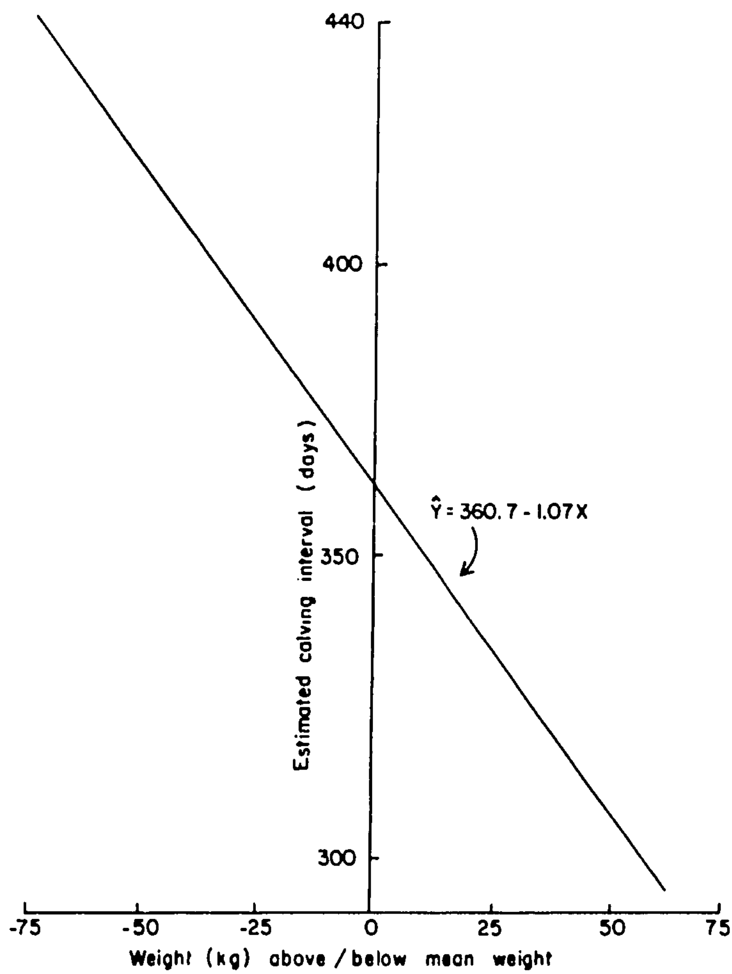
Figure 5. Relationship between calving interval and weight (WIACV-WCP) within year of earlier calving of supplemental cattle.



Body Weight at "Second" Conception

In the normal class of females, the optimal weight at "second" conception was 318 kg with a range between 310 and 330 kg (Figure 2). However, joining weight did not affect calving interval significantly. Group 4 females reconceived at an average weight of 311 kg, and heavier animals had a significantly ($P<0.05$) shorter mean calving interval. In the weaning trial, animals reconceived at an average weight of 351 kg, and for each kg increase in liveweight above the overall mean, there was a corresponding reduction ($P<0.01$) in calving interval of 1.1 days (Figure 6).

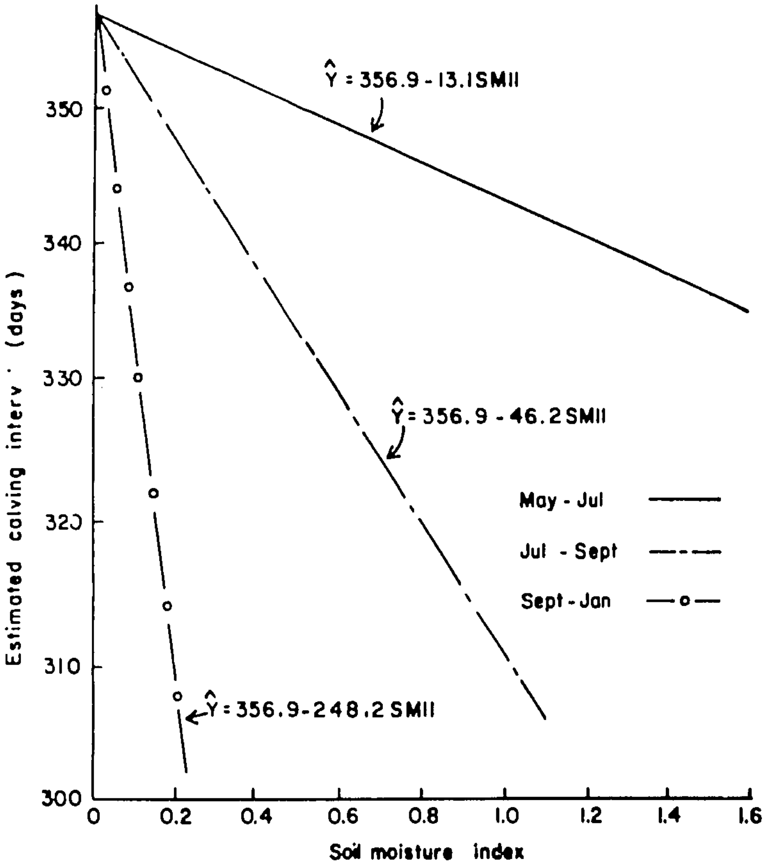
Figure 6. Relationship between calving interval and weight at "second" conception.



Soil Moisture Index

The effect of this factor on calving interval was linear and highly significant ($P<0.005$) but was modified by conception period as shown in Figure 7. In general, increase in SMI during the month prior to "second" conception was associated with a shorter mean calving interval. The response was greatest during the September-January conception period but was relatively marginal when conception occurred between May and September.

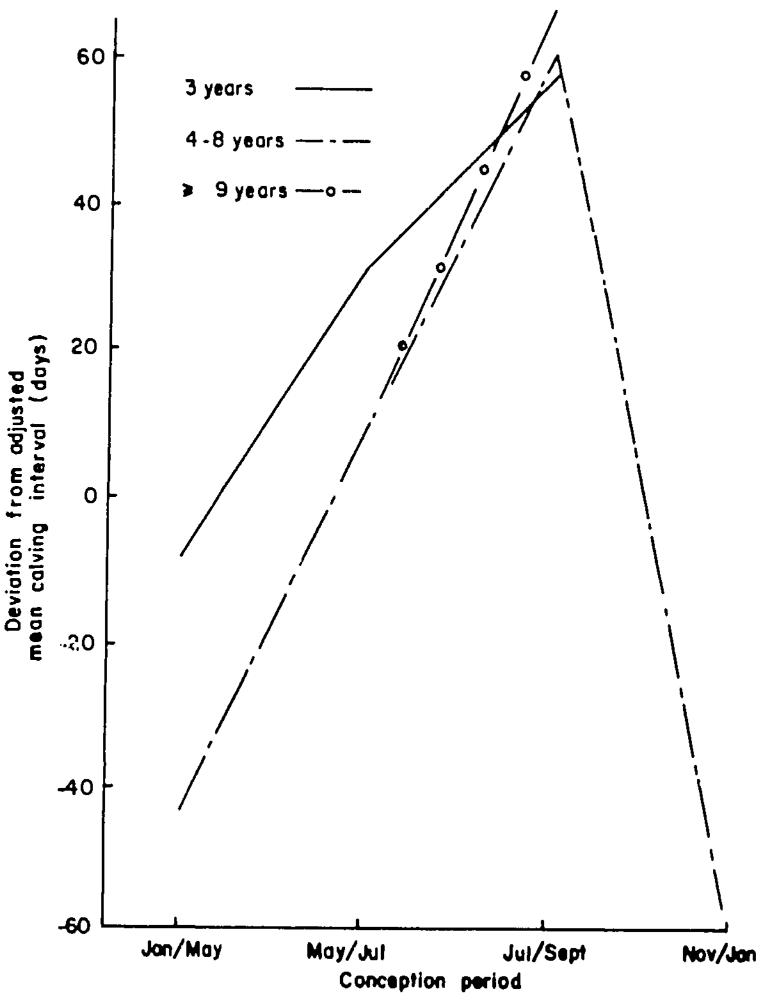
Figure 7. Relationship between calving interval and soil moisture index (SMII) within conception period of group 1 females.



Age of Breeding Females

When evaluated within conception period, age of animals had a highly significant ($P<0.005$) influence on calving interval (Figure 8). The three-year-old females that conceived between January and July had a longer mean calving interval compared to the 4 to 8-year-old cows. The shortest intervals were achieved by the 4 to 8-year-old cows which conceived between November and January. Regardless of age, all animals that reconceived between July and September had long intervals.

Figure 8. Effect of age at calving (years) within conception period on calving interval of group 2 females.



Dam's Previous Parity

The effect of this parameter became marginally significant ($P<0.05$) when evaluated in the context of conception period (Figure 9). Heifers that conceived between January and July had longer calving intervals compared to previously dry cows. Reconception between November and January was associated with shorter calving intervals regardless of previous parity.

Year of "Second" Conception

Year effects on calving interval were highly significant ($P<0.005$). Females that conceived during 1973 (late), 1975 and 1977 had shorter intervals compared to those that conceived during 1973 (early) and 1976.

Role of Supplementation

Dry season supplementation had a significant effect on calving interval, but this was modified by a number of factors:

Age: Without supplementation, the 5 to 9-year-old cows had calving intervals which averaged 38 days shorter than the mean for the 4-year-old females (Figure 10). Supplementation, whether before or after calving, only maintained calving intervals of the mature cows at average levels. However, there was a dramatic reduction in the interval when the 4-year-old females were supplemented after calving.

Previous parity: Females that suckled calves during the previous year responded positively to supplementation especially when given after calving (Figure 11).

Year of supplementation: While supplementation reduced calving intervals during 1978 and 1979 (post-parturient), it was virtually useless during 1980 (Figure 12).

Month of "earlier" calving: Females that calved between March and early May had shorter calving intervals compared to those that calved during January and February (Figure 13). However, with no supplementation, the 4-year-old females that calved during April and May had long intervals (Figure 14).

Energy versus energy + urea: Differences in the effects of these nutrients when given pre-partum were not significant.

Figure 9. Effect of previous parity within conception period on calving interval of group 4 females.

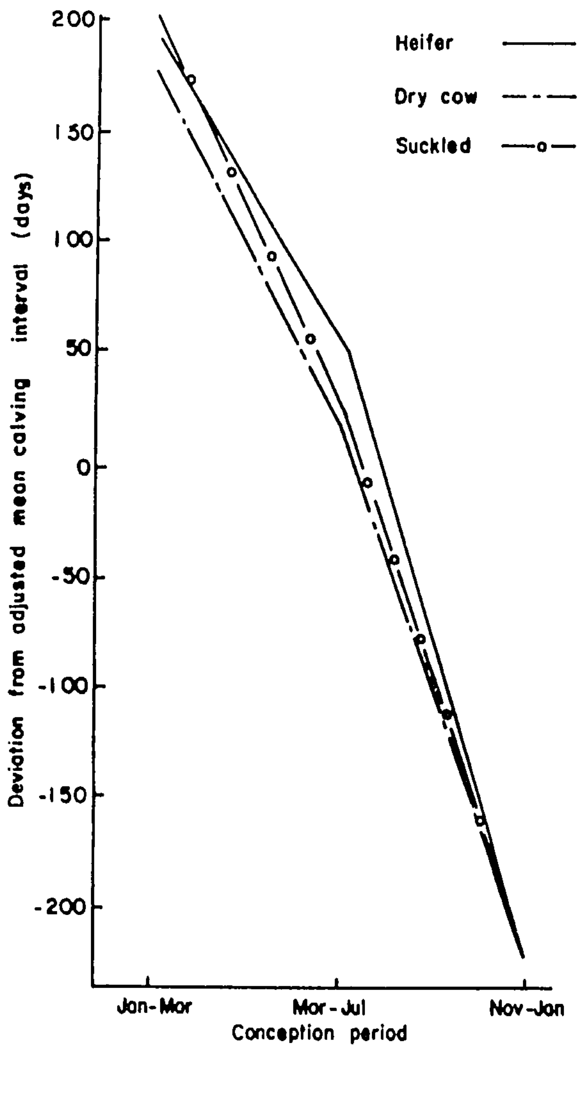


Figure 10. Effect of age calving within feeding regime on calving interval of supplemental cattle.

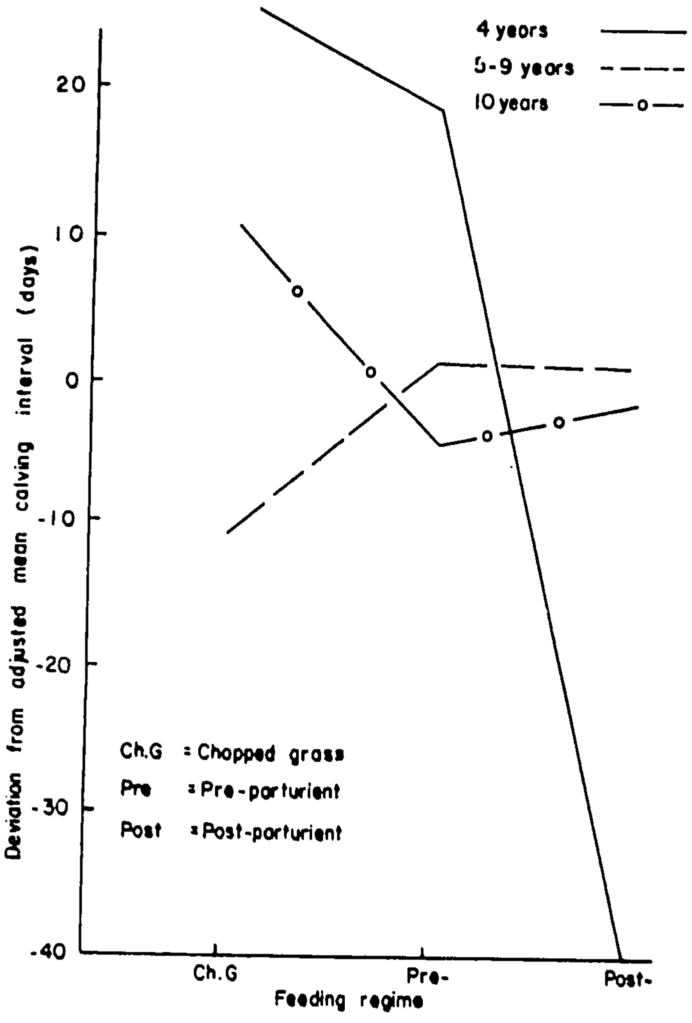


Figure 11. Effect of previous parity within feeding regime on calving interval.

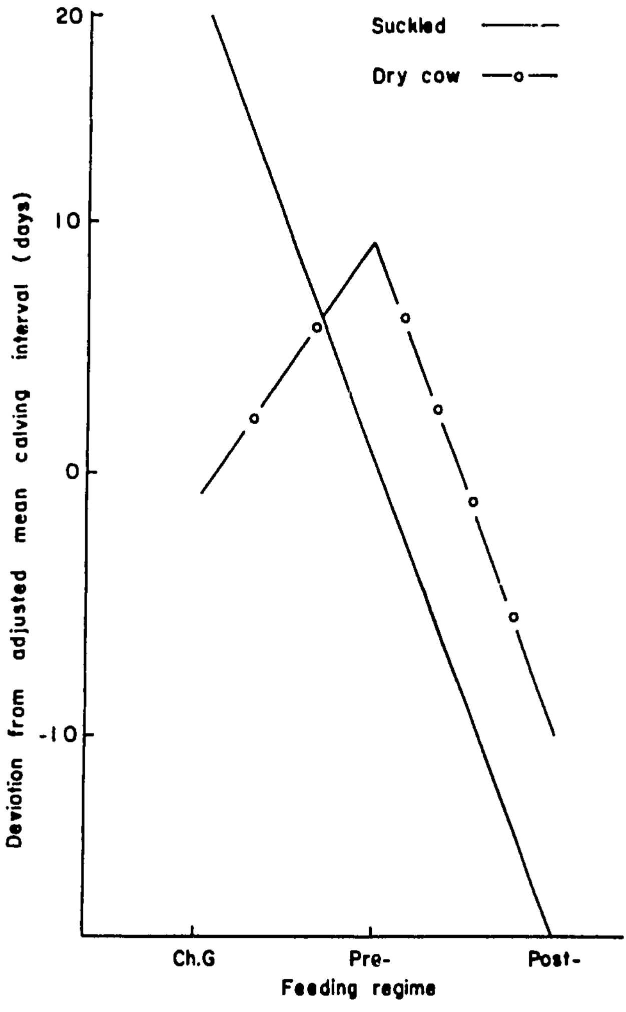


Figure 12. Effect of feeding regime within calving year on calving interval.

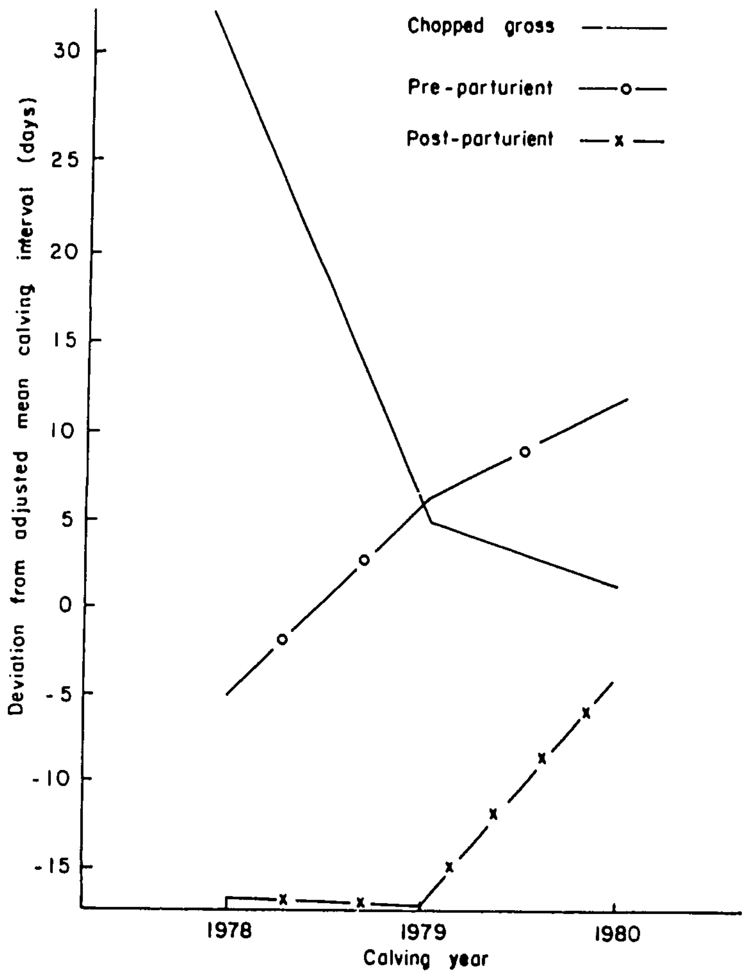


Figure 13. Effect of age (years) within month of earlier calving on calving interval of supplemented cattle.

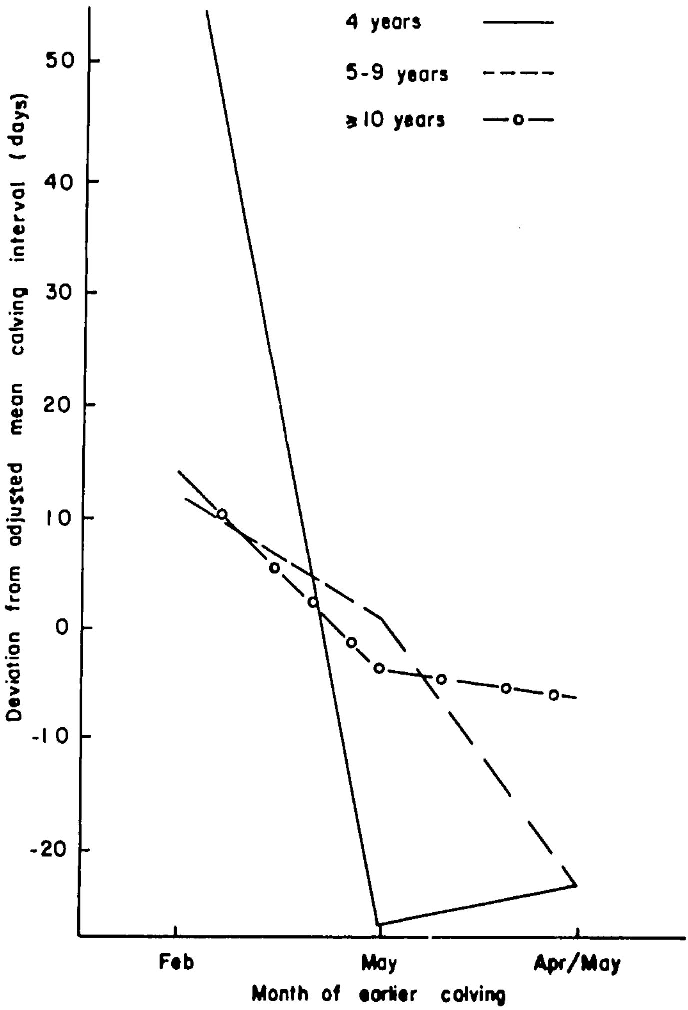
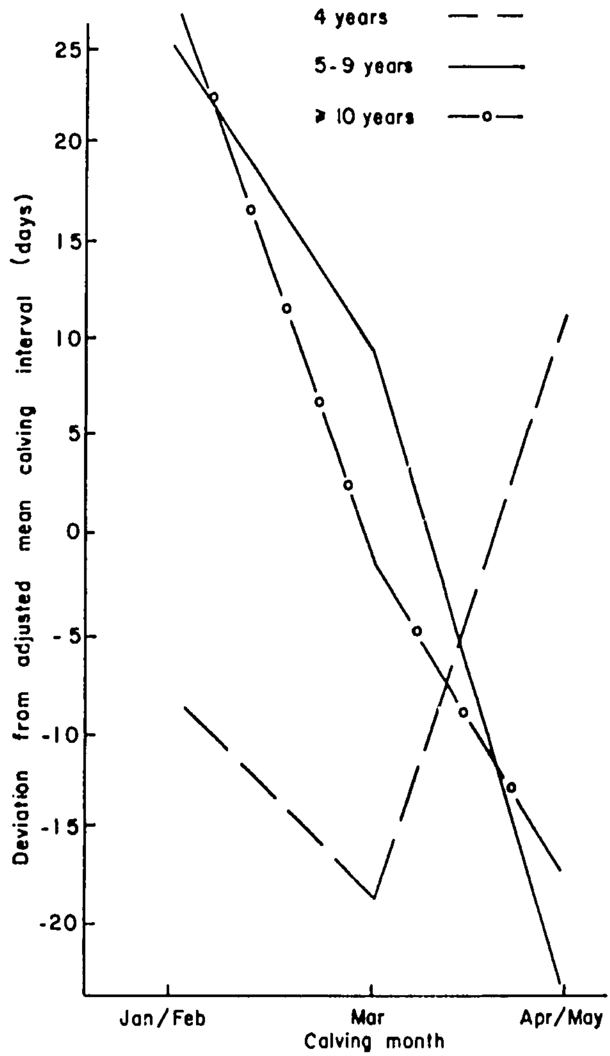


Figure 14. Effect of dam's age at weaning within subsequent calving month on calving interval.



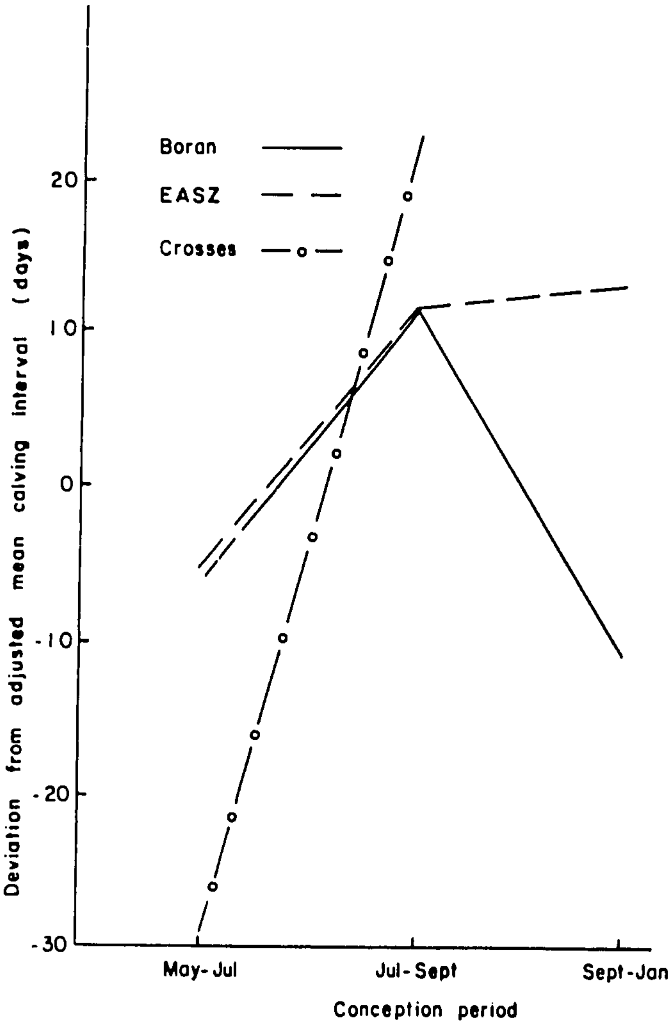
Effects of Weaning

Calving intervals increased marginally ($P<0.05$) by 0.2 days for each day increase in the period before weaning was effected. There was some indication that the 4-year-old females that weaned calves at the end of September had a shorter mean calving interval than that of females that weaned calves at the end of October, otherwise the effect of weaning month *per se* was marginal ($P<0.05$). As weaning progressed from year to year, the 10-year-old-and-above cows had calving intervals which averaged 32 and 21 days longer than for the 4- and 5 to 9-year-old females respectively. In general, effects of weaning on calving interval were marginal.

Dam's Genotype

The influence of this parameter was significantly ($P<0.05$) modified by conception period (Figure 15). Both the EASZ and the Boran females had similar calving intervals except during the September-January conception period when the latter breed had shorter intervals. The crosses that conceived between May and July had calving intervals which averaged 30 days below the adjusted overall mean of 357 days. Animals of all genotypes which conceived between July and September had long intervals. With supplementation, the Boran crosses had significantly ($P<0.01$) shorter calving intervals than pure Borans.

Figure 15. Effect of breed type within conception period on calving interval of group 1 females.



DISCUSSION

The highly significant main effects and interactions with body weight changes, soil moisture index, age, previous parity and dam's genotype made conception period one of the most important factors affecting fertility of grazing beef cattle at Athi River Ranch. High fertility was achieved during the November-January conception period which normally covers the "short rains" with high temperatures. The high fertility observed between January and March (Figure 8) could be due to increased sexual activity mainly as a result of high temperatures (Anderson, 1944). However, in rather striking contrast, group 4 females that conceived during the same period had a long fertility (Figure 9). Considering that the number of females that conceived during this period in group 4 was much greater than that in group 2 (Table 1), it would appear that inadequate grazing had a more marked adverse effect on fertility than the influence of increased temperature and sexual activity. Low fertility observed during the cold and dry period between July and September could be due to a level of intake sufficient to bring about ovulation but grossly inadequate for full manifestation of oestrus.

The highly significant year effects reflected important variation in fertility from year to year. Admittedly, a large proportion of year effects would be confounded with variation associated with conception period. But since it is possible that factors other than conception period could contribute significantly to the observed variation, inclusion of year effects in the evaluation model would still be justified. Age of bulls and management practices relating to stocking rate, mineral supplementation and culling programmes are some of the factors which could vary from year to year.

Bishop (1978) reported high conception rates following rainfall during the previous year. However, in Kenyan rangelands with such tremendous variability in rainfall both annually and seasonally (French, 1957), it would be desirable to correlate fertility with rainfall within the immediate past so that corrective measures could be instituted in good time. In Australia, Andrews (1976) reported a high correlation between conception rate and rainfall with a one-month lag. Working at Athi River Ranch, Potter (1985) observed that liveweight gain was correlated with rainfall occurring between three to six weeks previously. The period of SMI evaluation in this study coincided with the one used by Andrews (1976) but did not quite correspond with the one evaluated by Potter (1985). Further work is needed to pin-point this period more precisely. Potter (1985) has suggested that use of rainfall data was just as good as the more elaborate and often cumbersome water balance information involving evapotranspiration data. Although rainfall may be an important factor, Andrews (1976) contended that a period of one month was not sufficient time for pastures to grow and improve body condition and hence conception rate. He postulated that increased fertility was likely to be due to either a change in the nutritional composition of the pastures or an increase in the rate of intake or both through the action of the hypothalmus and/or the pituitary. However, it is important to note that rangeland vegetation at Athi River Ranch grows very fast and matures very quickly (Karue, 1972; 1974), and so it may have a short-term direct effect on body condition and hence fertility.

The debate continues as to whether the animal's ability to conceive was a function of its absolute body weight *per se* (Lammond, 1970; Grosskopf, 1980) or weight change prior to conception (Elliot, 1964, cited by Topps, 1977; Capper *et al.*, 1977; Thorpe *et al.*, 1981). While suggesting the concept of a target joining weight, Lammond (1970) had intimated that for each cow, depending on breed, age and year, there was a certain range in body weight and body condition required for conception. By implication, therefore, it did not matter whether animals lost or gained weight during the breeding season provided their liveweight was maintained above a certain minimum. The ability to maintain weight would depend, among other things, on the current lactational stress on the animal, hence the reason why researchers evaluate body weight in heifers, dry or lactating cows (Kidner, 1966; Sacker *et al.*, 1971; Morley *et al*, 1976). Such evaluation would be possible if fertility was considered in terms of calving date rather than calving interval. Another aspect is whether the various workers were evaluating absolute or proportionate weight changes. A proportionate weight change such as that used in this study with weight at "second" conception as a reference point would render changes in small animals (though of the same breed) comparable to similar changes in bigger ones. It seems as if both body weight and weight change operate singly or simultaneously to influence fertility depending on the lactational and/or nutritional status of the animal. For instance, although animals in the normal class reconceived at an average weight of 320 kg well within the optimum range of 310 to 330 kg for this group of animals, influence of body weight was not significant. This could have been due to the adverse effect of suckling reported by Wiltbank and Cook (1958) and Hutchison (1983).

Group 4 females had dried off at the time they reconceived, and the effect of joining weight was able to be manifested, though marginally due to the fact that animals conceived at an average weight of 311 kg which was at the bottom of the required range in body weight. Under these circumstances, both body weight at joining and weight change affected fertility simultaneously. Animals reconceived between September and January and during 1976 at average weights of 308 and 298 kg respectively. Both weights were below the minimum weight required for conception, and animals that had a higher fertility were those that gained or lost less body weight during the month prior to conception. With favourable nutritional conditions between May and July (Figure 2), during 1975 (Figure 3) and 1979 (Figure 5), animals reconceived at average weights of 330, 311 (half the number of females were the small EASZ) and 352 kg respectively. Under these conditions, effect of weight change was marginal and animals could gain or lose weight without jeopardising their fertility. The picture during 1973/74 (Figure 3) was somewhat confusing probably due to the fact that fertility was evaluated over a two-year period. In any case, the sample size during 1973 and 1974 was far too small to warrant any serious consideration of the effects during these two years. Curvilinearity in response of weight change could also be ignored.

Dry cows (group 4) and females that had settled down after calving before they were re-introduced to the bulls (group 2) tended to gain weight prior to conception to the detriment of fertility. However, in normal ranching situations, animals would be lactating at the time they reconceive with minimum chances of overweight. Failure to register significant effects of weight change between one month after calving and conception could have been due to the rather limited variation in climatic conditions during the pre-selected breeding season between May and July. However, it was evident that weight changes occurring near conception exerted a much greater effect on fertility than changes far removed from conception. What is, perhaps, perplexing is the revelation by Thorpe *et al.* (1981) that liveweight was merely an approximate indicator of the nutritional status of a beef animal. These workers postulated the existence of an intricate relationship between nutrition, hormonal control, lactation and fertility in which the post-partum period with its associated lactational stress was considered more important than variation due to liveweight. Since this relationship is still vaguely understood, monitoring of body condition as suggested by Andrews (1976) together with proportionate body weight changes during the month prior to breeding would give a reasonable indication of the fertility status of a grazing beef animal.

Supplementation of beef cattle with energy (Wiltbank *et al* 1962 and 1964; Dunn *et al.*, 1969) or nitrogen (Elliot, cited by Christie, 1962; Siebert *et al.*, 1976; Holroyd *et al.*, 1977) has been a normal practice to improve fertility but results have not been consistent. For instance, in Botswana, Capper *et al.* (1977) observed no response to stimulatory licks of molasses and urea by dry cows or cows with calves older than five months. More recently, Holroyd *et al.* (1983) supplemented beef cows with urea and molasses but observed no effect on fertility. In this study, improved fertility was observed in the four-year-old and previously suckled females. It seems imperative, therefore, that assessment of the effect of supplementation should be done in the context of age and previous parity. Failure to detect differences in the effect of grain versus grain plus urea feeding could be attributed to the favourable climatic conditions especially during 1979 and 1980 which made it possible for animals to derive most of their nutrient requirements from pasture alone. It is worth noting that the last trimester of pregnancies at the ranch coincided with the period covering the "short rains" between November and December. Under such conditions, Orskov (1982) suggested that nitrogen requirements for pregnancy could be met by microbial protein synthesis alone. However, there is a tremendous increase in the nutritional requirements for lactation and reconception (Crampton and Lloyd, 1959), hence the significance of post-calving supplementation. It would, therefore, be of interest to investigate the effect of nitrogen and energy sources when given post-partum. Since all indications pointed at conception as the most critical period, it would be necessary to pinpoint more precisely how soon after calving should supplementation be given. Because of the intricate relationship between non-protein nitrogen (NPN) and carbohydrate metabolism and utilisation (Orskov, 1982), further investigations should be focused not on the relative importance of NPN and energy but rather on the proportion of rumendegradable and undegradable nitrogen relative to metabolisable energy intake.

The effect of age on fertility of beef cattle is an indirect one through its influence on body condition to which young cattle are more sensitive (Andrews, 1976). As body condition was related to liveweight, Wiltbank and Spitzer (1978) have stressed the significance of allowing young cattle to attain a target weight and age before first mating - the weight and age varying according to breed. Under East African conditions, Macfarlane and Worrall (1970) had indicated that puberty in Boran heifers occurred at approximately 60% of the mature body weight. However, mere attainment of puberty is not enough as young cattle are expected to conceive, carry the foetus to full term, rear the calf successfully and reconceive at the earliest opportunity. It is possible that the 250 kg liveweight stipulated for first breeding of heifers at the ranch was lower than the threshold joining weight especially in crosses. This would not only delay reconception but could curtail their productive life. If anything, it would be better to breed heifers too late than too soon. Young beef cattle were more vulnerable to adverse nutritional conditions at post-partum oestrus. However, their fertility improved as the post-calving period before joining with the bulls increased from about five months onwards. There was evidence from the weaning trial that highest fertility was achieved by the four-year-old females. The implication of these observations is that young cattle should be allowed about five months after calving before joining with bulls for their second mating season. This would mean that first breeding in heifers and that of the main herd would be out-of-phase, although all indications were in favour of seasonal mating. However, earlier breeding in heifers would necessitate their separation from the main herd which would facilitate closer attention and feeding to ensure high fertility. A suggested package for young beef cattle would be (a) mating between November and January or, in general, immediately after a rainy period (b) separating and mating approximately three months before the main herd to synchronize second mating with the rest of the herd and (c) providing a supplementary diet after first calving.

The timing of the breeding programme at the ranch did not permit evaluation of the effects of calving months other than those between late January and early May. However, it was evident that animals that calved down during the dry season in January and February had a low fertility. This could be due to failure to regain lost body weight (Kidner, 1966) but as Christie (1962) had indicated, dry season loss in body weight *per se* did not, necessarily, reduce fertility as long as the animal was able to recoup during the subsequent wet season. Animals that calved down during March had a high fertility which confirmed Daly's (1971) suggestion that calves should be dropped at the end of a dry season. The older cattle that calved down during the rainy season in April-May seemed to get away with less favourable nutritional conditions at post-partum oestrus probably because of their ability to draw on body reserves accumulated during the wet period (Orskov, 1982).

There were indications to suggest that previous parity had an influence, albeit small, on fertility. Results from various workers reporting on this parameter are rather inconsistent (Christie, 1962; Buck *et al.*, 1976; Thorpe *et al.*, 1981). It would appear that in order to make meaningful comparison in fertility, one would have to consider previous parity in the context of conception period. When nutrition was adequate, for instance during November-January conception period, or when supplementation was given after calving, influence of previous parity became insignificant. Generally, carry-over effects arising from previous parity were of less importance in the fertility complex. This should not be confused with the overwhelming influence from current lactational stress on the animal (Crampton and Lloyd, 1959; Trail, 1968), and the whole idea behind weaning is to remove this stress thereby ensuring that animals attain the body weight and body condition required for reconception. Lammond (1970) had suggested increasing body weight and condition before calving and attempting to hold this condition up to the breeding season. This could be achieved by early weaning but because of seasonality in pasture productivity (Karue, 1972, 1974), it would be difficult to maintain body weight. Besides, results of this study indicated that fertility was not always correlated with body weight at calving. The other alternative also suggested by Lammond (1970) was to allow cows to calve down in reasonable body condition and feed heavily up to conception. This would be a much more practical method which was supported by results of this study relating to post-partum supplementation.

The question of weaning month necessitated some consideration because of the observed sensitity to pasture by the early weaned calves (Schotter and Williams, 1975) on one hand and the need to prepare the breeding female for subsequent calving and, more importantly, reconception on the other. However, effects of weaning month were, at best, only marginal probably because of a closed breeding period and hence weaning season. Thus, in considering the effects of lactation, it would be more important to pay particular attention to when animals are due to calve down so that they can be supplemented for early reconception rather than attempting to increase body weight and body condition at calving by early weaning.

The EASZ females exhibited fairly consistent fertility levels throughout the year, an observation that was consistent with the findings of Galukande *et al.* (1962). Zebu cattle are indigenous in East Africa (Mason and Maule, 1960) and would be expected to have adapted themselves to fluctuations in feed supply and related factors from out-of-season rains and prolonged droughts. Adaptability has been attributed to their ability to lay down fat on a lower plane of nutrition (Mason and Buvanendran, 1982). Fertility of the Borans was, by and large, similar to that of the EASZ which supported the observations reported by Trail (1968) at Ruhengere Ranch in Uganda. However, there was evidence to indicate that the Borans had a higher fertility during the last quarter of the year when pasture productivity was adequate.

Results of cross-breeding to improve fertility have been inconsistent. Some reports have indicated a reduction in age at first calving (Mahadevan and Hutchison, 1964) and increased manifestation of oestrus in cross-bred zebu cattle (Swensson *et* al., 1981). Observations from this study tended to tip the balance in favour of Boran crosses under conditions of adequate nutrition. High fertility could be due to heterosis. However, this could not be confirmed due to lack of reciprocal crosses. Although it is desirable to maintain the indigenous zebu germplasm, the prospects of increased beef productivity from rangelands based on the Boran and its crosses look very promising.

CONCLUSIONS

Fertility in range-fed beef cattle is a very complex physiological process involving the interplay of a number of factors. These factors are overwhelmingly climatic in origin which means that environmental conditions especially nutrition and management have to be tailored for the benefit of the animal. Nutritional and management factors immediately before and during the mating season had the most significant and far-reaching effects on fertility. Even during the conception period, influence of nutrition and related factors such as rainfall, body weight and dam's age varied from season to season and was modified by other factors which, all working in concert, complicated the situation even further.

Fertility was seasonal. Consequently, seasonal mating would be advocated. High fertility was observed between November and January followed by May-July. The significant year effects reflected mainly seasonal effects although variation across years could be attributed to changes in feeding, mating practices and age of bulls. Increased rainfall during the month before conception was associated with high fertility. The effect was seasonal which underscored the significance of conception period and seasonal mating.

The target joining weight was around 318 kg with a range between 310 and 330 kg. Heavier cows at conception were more fertile than lighter ones, but the depressing effect of suckling could counteract that of body weight unless joining weight was well above 318 kg. Animals that gained body weight or suffered less weight loss during the month prior to conception had a higher fertility. Previously dry cows tended to gain weight prior to conception and gave a better indication of fertility status than weight changes far-removed from conception.

Dry season supplementation only helped to maintain fertility of older cows at average levels. However, it improved fertility of young and previously suckled females especially when given post-partum. There was no significant difference in the fertility of cows that were supplemented before calving with energy or energy plus urea.

Fertility improved marginally following early weaning. Some benefit was achieved when young females weaned their calves in September following a dry and cold season. Generally, effects of weaning were of less significance in the fertility complex.

Fertility also improved as the dam's age increased from three years onwards but declined after about nine to ten years.

Young cattle were more vulnerable to adverse post-partum nutritional conditions. However, their fertility improved when they were allowed about five months after first calving before mating for the second parity. This would mean separation and mating of heifers some three months or so before breeding in the main herd to be able to synchronise their second mating with the rest of the herd.

Effect of previous parity on fertility was marginal depending on the nutritional level during the breeding season. Under grazing conditions without supplementation, dry cows were more fertile than previously suckled animals. This trend was reversed with supplementation. Females that conceived between November and January had a high fertility regardless of previous parity. Fertility levels of the East African shorthorn Zebu and Boran cows were similar except during the last quarter of the year when the latter breed had a better performance. Generally, crosses had a high fertility following a rainy season. However, with dry season supplementation, performance of the Boran crosses excelled the rest of the genotypes.

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THE ROLE OF WATER PULSES ON THE PRODUCTIVITY OF SAVANNA ECOSYSTEMS IN KENYA

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Abstract

Seasonal patterns of transpiration, leaf conductance and leaf water potential of herbaceous and shrub plant species in semi-arid savanna ecosystems were determined over a growing season. Transpirational use of water for the shrub species ranged between 20 micrograms/cm^{-2} S^{-1} and 30 micrograms/cm^{-2} S^{-1}. The deep-rooted shrub species maintained favourable leaf water balance and remained green over the entire growing season. The water response curves for the shallow-rooted plants indicated that they had little control over their water economy. Environmental processes leading to bush encroachment seem to be closely related to water response patterns of semi-arid savanna ecosystems in Kenya's pastoral grazing lands.

INTRODUCTION

Savanna grasslands in Kenya occupy areas of marginal rainfall that constitute over one half of the total area of the country (Pratt *et al.*, 1966). Water availability is the major driving variable controlling biological activity and regulating productivity of savanna ecosystems (Walker *et al.*, 1981; Maranga *et al.*, 1983; Maranga, 1986). Rainfall events are sporadic and often occur in irregular pulsations of short-lived storms (Griffiths, 1972). Effective rainfall recharges soil moisture for a specific period of time. The time elapsing between a change in soil-water status and an observed change in a plant process constitutes the response period (Sala *et al.*, 1982). The response period of water-controlled processes is not fixed but is, at least partially, a function of the degree of water stress to which plants were previously exposed. The efficiency of utilisation of water input will decrease as the response period increases and therefore will depend on the water status (leaf water potential) of the plants prior to a rainfall event (Sala *et al.*, 1982).

This paper attempts to evaluate water responses of native shrub and grass species to fluctuating soil water in the semi-arid lands of Kenya. Plant variables used in this study to gauge plant water responses include leaf water potential and transpiration both of which are important determinants of plant productivity in semi-arid areas. The adaptive mechanisms that explain the observed responses will be deciphered.

MATERIALS AND METHODS

Data and conclusions presented here come from field experiments conducted at the National Range Research Station, Kiboko. Mean annual rainfall is 600 mm based on over 70 years of data from

Makindu Meteorological Station located near the research station. Rainfall is bimodally distributed. The "long" rains last from March to May; the "short" rains begin in or around October and end in December.

Detailed descriptions of the vegetation physiognomy of the study area are documented by Michieka and van der Pouw (1977). The vegetation of the experimental area can be described generally as open-wooded grasslands. There are scattered trees of *Acacia seyal*, *Acacia tortilis* and *Commiphora riparia*. There is a patchy understorey of shrubs of *Grewia* sp., *Duosperma* sp. and other genera scattered in a matrix of grassland characterised by *Themeda triandra*, *Panicum maximum*, *Digitaria macroblephara* and *Chloris roxburghiana*.

Field studies of soil water potential distribution with depth on sites that were dominated by *Digitaria macroblephara*, *Panicum maximum*, *Acacia tortilis*, *Commiphora riparia*, *Grewia villosa* and *Hermania alhensis* were carried out by means of a modified version of Spanner's (Spanner, 1951) Peltier thermocouple psychrometer installed at 10, 30, 60, 90 and 120 cm depths. The Peltier psychrometer system consisted of a microvoltmeter system, a control unit to supply current for Peltier cooling and a thermo couple psychrometer. The Hewlett Packard Model 419A (Hewlett Packard Englewood, Colorado) dew point microvoltmeter was used in conjunction with the thermocouple psychrometers calibrated for the five depths. Transpiration and diffusive resistance were measured by means of a steady state porometer (Li-Cor LI-1600 diffusive resistance porometer) between 10.00 a.m. and 2.00 p.m.

RESULTS

Effective rainfall contribution recharged the dry soils increasing soil water potentials from -10 MPa in early December to field capacity conditions by mid-December in the surface depths of 10 cm and 30 cm. Soil water potential in the deeper depths of 60-120 cm oscillated between approximately -7 MPa and -3 MPa over the same period (Figure 1). The wetting phase in the short rainfall season maintained field capacity conditions in the surface depths for a period of approximately three weeks. As soil water input declined, a sharp drop in soil moisture potentials occurred for the shallower soil profiles with only a gradual decline for the deeper soil horizons.

Leaf water potentials for the shrub and herbaceous plant species (see Figure 2) in mid-December were characteristic of non-water deficit conditions. In the course of the wetting phase, leaf water potentials barely dropped below -4 MPa. Thereafter, all other plant species except *Commiphora riparia* exhibited fluctuating trends of leaf water potentials indicating a cessation of soil water input coupled by soil water depletion to meet transpiration demand. The lowest leaf water potential of -7 MPa was recorded for *Digitaria macroblephara* and *Grewia villosa* between January and February. *Commiphora riparia* maintained leaf water potentials at levels greater than -2 MPa throughout the growth cycle. Leaf water potentials for *Acacia tortilis* fluctuated between -4 MPa and -1 MPa over the same

Figure 1. Soil water potential by soil depth.

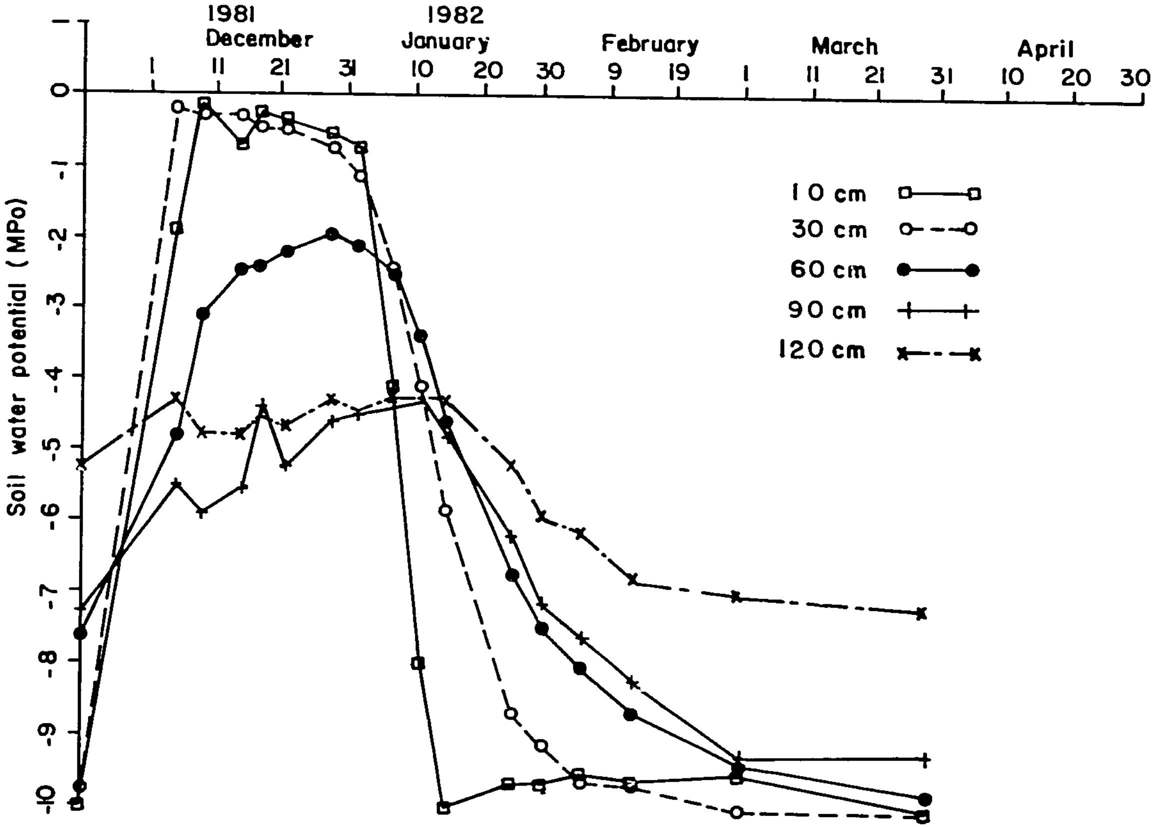
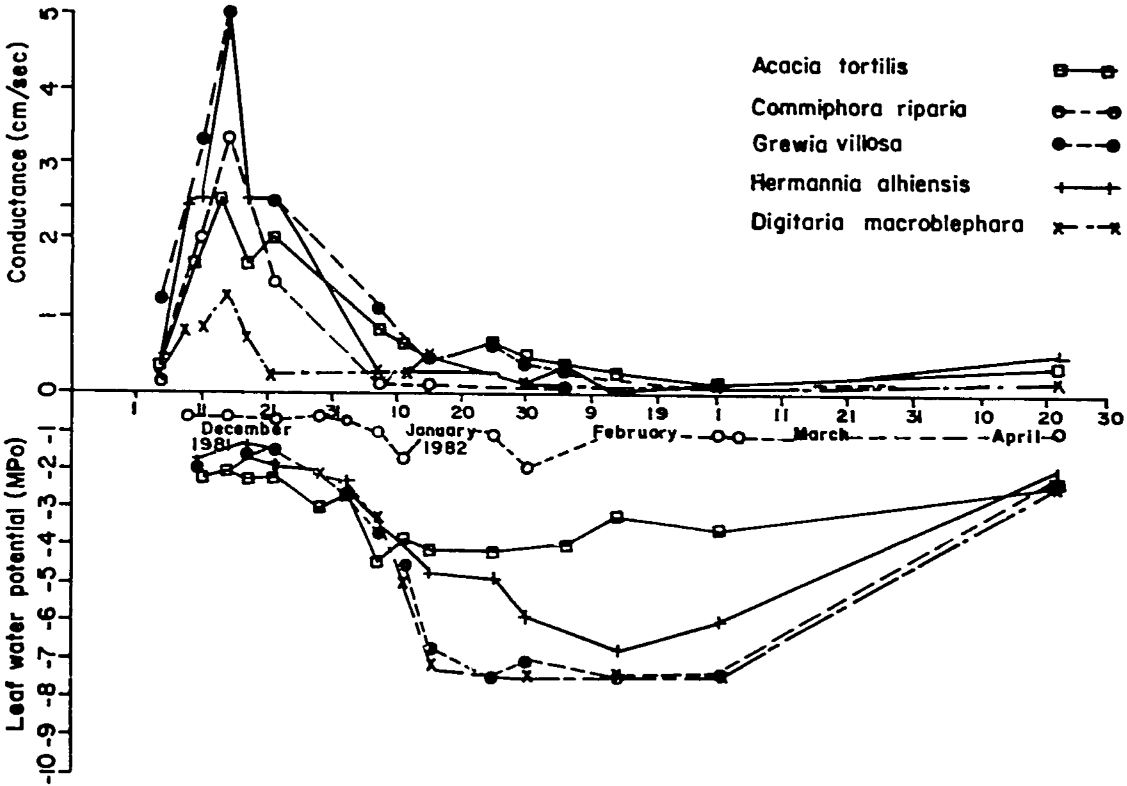


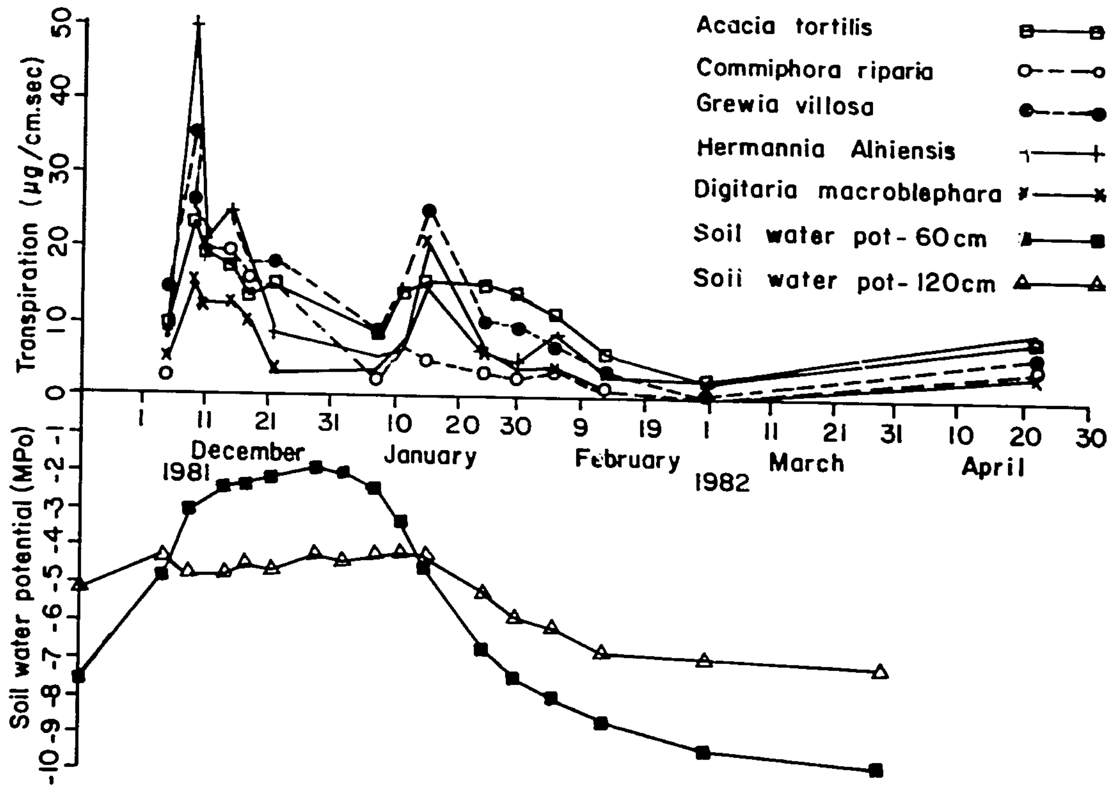
Figure 2. Conductance and leaf water potential by species.



period. Stomatal conductance exhibited a pattern that was approximately inversely related to leaf water potential at least for the herbaceous plant species studied. Stomatal conductance values peaked in December coinciding with thu phase of active soil water replenishment.

Transpiration rates of the shrub species in the course of the wetting phase ranged between 20 micrograms/cm^{-2} S^{-1} and 30 micrograms/cm^{2} S^{-1} whereas that of *Digitaria macroblephara* rarely exceeded 20 micrograms/cm^{-2} S^{-1} (see Figure 3).

Figure 3. Transpiration by species and soil water potential by depth.



DISCUSSION

In the course of the wetting phase, water was available within the rooting zone and all species maintained a favourable water balance. However, as soil water depletion continued to meet the rising evapotranspiration demand as the dry season advanced, moisture supplies were exhausted from the top soil profiles. Shallow-rooted *Digitaria macroblephara* and *Grewia villosa* registered unfavourable water balance. The deep-rooted *Acacia tortilis* appeared green for the entire growth cycle indicating that water was available within its rooting zone. *Commiphora riparia* drops most of its leaves and maintains a succulent stem in the course of the dry season. In this study, *Commiphora riparia* maintained a favourable stable leaf water potential suggesting an efficient regulation of its water economy facilitated by water conservation mechanisms. Feinner (1981) in a study of two *Commiphora* sp., *Adonsonia digitata* and *Sterculia rhynchocarpa* reported that these species are relatively efficient in conserving their water content.

The specificity in water use patterns of semi-arid savanna ecosystems places important restrictions in their responses to management interventions. Excessive removal of herbaceous biomass by grazing animals would influence the total water input reaching the various soil profiles. Walker *et al.* (1981) reported that on medium to heavy textured savanna soils, decreases in infiltration rates resulting from capping of the soil surface pores were associated with a decline in grass and litter cover.

In most of the Kenyan pastoral grazing lands, excessive depletion of grass cover through overgrazing has resulted in a serious problem of bush encroachment. The environmental processes leading to bush encroachment seem to be closely tind to the differential water use patterns associated with morphological characteristics facilitating exclusive use of water available at different soil profiles.

CONCLUSIONS

Soil water potential distribution in the soil profiles of semi-arid ecosystems is closely related to the nature of precipitation events and soil water depletion characteristics. The soil moisture response curve is characterised by rapid oscillations in the levels of soil water potential in the top soil profiles. Gradual declines in soil water potential occur with increase in depth and progressive advancement of the dry season.

Shallow-rooted plants like *Digitaria macroblephara* and *Grewia villosa* tend to take exclusive advantage of water availability in the top soil profiles when precipitation events occur. As the dry season progresses, these plants quickly show unfavourable water balance suggesting little control of their water economy.

In general the seasonal patterns of transpiration, leaf conductance and leaf water potential suggested that the shrub species utilised more water per unit area than the herbaceous plant species.

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NUTRITIONAL VALUES OF THE DIETS OF MAASAI CATTLE

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Abstract

The most grazed grass species were Chloris roxburghiana, Digitaria macroblephara *and* Pennisetum mezianum. *Season, area and the interaction between area and season were significant (P<0.05) sources of variation for the diet nutritive values. The least squares means of the diet nutritional values were: 8.1, 69, 49, 0.26, 0.5 and 0.22% for CP, NDF, IVDMD, P, Ca, Mg, and 1703, 6.2, and 67 ppm for Fe, Cu and Mn respectively.*

INTRODUCTION

The performance of pastoral cattle is usually described as poor. For instance, weaning weights of calves are less than 65 kg (Nicholson, 1983; Diallo *et al.*, 1981), calving intervals are longer than eighteen months (Wagenaar *et al.*, 1986; Otchere, 1986) and mortality rates of calves in some years are as high as 50% (Williamson and Payne, 1978; Mahadevan, 1966). However, it is known that the performance of cattle is a function of the breed, forage intake and the environment, including management and climatic factors. In turn forage intake by cattle grazing extensive rangelands is influenced by the age and physiological status of the forage on offer. In extensive production systems, of the three factors determining intake, forage quality is of greatest biological importance as compared to the others, because man has the least influence. This is so because forage quality is determined by climatic and soil conditions. To measure the forage quality and its implications on forage intake in a pastoral system a research was initiated by the International Livestock Centre for Africa (ILCA) as part of a three-year study of the Maasai livestock production. It comprised three group ranches with five grazing areas, located in the eastern area of Kajiado District in Kenya.

MATERIALS AND METHODS

Oesophagally fistulated (OF) cows were used for forage sampling. Sampling was done twice in a day to coincide with AM and PM grazing peaks. Sampling during grazing peaks were preferred in order to minimise contamination of the extrusa with regurgitated material. During each sampling session three OF cows were used and extrusa of approximately one kg was collected at each sampling from each OF cow. The collection period averaged 25 minutes. Extrusa samples collected in wet seasons were transferred into plastic bags and placed in a cool-box containing dry ice before being shipped to Nairobi for oven drying. In dry seasons the extrusa samples were first placed on wire mesh trays for sun drying. All extrusa samples on reaching Nairobi were dried in a Memmert oven at 60° C. Before milling by a Christy mill through a one-mm screen, the samples were fractionated into whole sample, leaves, and sheaths together with stems.

Laboratory analysis consisted of Kjeldahl, fibre analysis (Goering and van Soest, 1970), dry-matter solubility using double enzyme method of pepsin and cellulase, and atomic absorption spectrophotometry and flame photometry for minerals.

The five-minute method was used to mimic grazing of the cattle. At the end of each five-minute period the species of grass or browse grazed was identified and recorded. Six areas and four seasons were studied.

For statistical analysis SPSS and least squares procedure of Harvey (1977) were used.

RESULTS

Botanical Composition of the Diet

Over the 84 cow days, 74 different species of herbs grasses and shrubs were foraged by cattle. The observation period covered four seasons and six areas. Since one of the seasons represented the peak of the drought of 1984, the Kiboko area was included in this season because the majority of the cattle were moved there. It was claimed the area was endowed with more herbage than the home grazing orbits. Tables 1 and 2 show botanical compositions by season and area respectively.

The dominant species in the diet were *Chloris roxburghiana, Pennisetum mezianum* and *Digitaria macroblephara* compromising at least 50% of the diet during the four seasons of 1983. Prominence of the first two species persisted even in the drought of 1984.

In the dry season cattle did not browse but grazed on other species more and for the first time on the litter. Compared with the dry season of 1983, in the drought season *Chloris roxburghiana, Pennisetum mezianum, Digitaria macroblephara, Aristida keniensis, Bothriochloa insculpta* and *Cenchrus ciliaris* were grazed less frequently and *Cynodon plectostachyus, Sporobolus fimbriatus, Chrysopogon aucheri, Setaria sphacelata,* browse, litter and others more frequently.

As for the seasons of 1983, the three main species in the diet of cattle in all five areas of sampling were *Chloris roxburghiana, Pennisetum mezianum* and *Digitaria macroblephara*. The rest of the diet varied as certain species were either dropped or included from respective areas. The average diet composition of the five areas was very different from Kiboko's where the cattle were sent during the drought of 1984. For Kiboko *Pennisetum mezianum* and *Digitaria macroblephara* ceased to be one of the three major species. Instead there came browse species and the litter with the former contributing 34% of the diet. For this area the diet consisted of less than 65% grass.

Table 1. Composition of diet selected by Maasai cattle by season (%).

Season Year	Dry/green Feb/Mar 1983	Green May/June 1983	Dry Sept/Oct 1983	Mean for 1983	Drought July/Aug 1984
Number of cow days	21	28	12	20	23
Chloris roxburghiana	20	24	19	21	13
Pennisetum mezianum	18	18	20	19	18
Digitaria macroblephara	20	18	11	16	7
Aristida kenyensis	8	7	4	6	NG
Cynodon plectostachyus	7	8	2	6	4
Sporobolus fimbriatus	10	6	NG	5	5
Chrysopogon aucheri	3	4	6	4	7
Bothriochloa insculpta	3	NG	8	4	3
Cenchrus ciliaris	NG	4	2	2	NG
Setaria sphacelata	NG	NG	NG	NG	3
Browse	3	5	NG	3	4
Litter	NG	NG	15	5	17
Others	8	6	13	9	19

NG = not grazed.

The diet preference index (Taylor, 1973) for the three major species ranged from 1.4 to 3.6, and their ground cover within the grazing orbits was more than the other species. Availability of these species was important in the determination of their selection. It should, however, be noted that these species are of high palatability compared with the others. Their selection, particularly for *Digitaria macroblephara* and *Chloris roxburghiana*, was due to availability and palatability while that of the less palatable *Pennisetum mezianum* was due only to availability.

Table 2. Composition of diet selected by Maasai cattle by area (%).

Area	Kavati	Ol-karkar	Ilkelu-nyeti	Oiti	Isupa-nani	Mean	Kiboko drought
Number of cow days	16	8	12	12	13	12	9
Chloris roxburghiana	13	21	21	30	17	20	17
Pennisetum mezianum	18	11	25	18	25	19	NG
Digitaria macroblephara	20	18	8	23	10	16	2
Cynodon plectostachyus	9	12	5	3	4	7	NG
Sporobolus fimbriatus	13	10	3	NG	4	6	NG
Aristida kenyensis	2	NG	8	11	9	6	NG
Chrysopogon aucheri	NG	NG	3	1	10	3	15
Bothriochloa insculpta	NG	3	4	4	NG	2	10
Cenchrus ciliaris	2	6	NG	NG	NG	2	NG
Ischaemum spp	2	2	NG	NG	NG	1	NG
Setaria sphacelata	2	NG	NG	NG	NG	0.4	NG
Browse	NG	3	2	7	2	3	34
Litter	6	4	9	NG	6	5	17
Others	13	10	12	3	13	10	5
Total	100	100	100	100	100	100	100

NG = not grazed.

Diet Quality

Oesophagally fistulated cows were used to determine forage quality by season and the study area. Analysis of 126 samples for crude protein (CP), neutral-detergent fibre (NDF), *in-vivo* dry-matter digestibility (IVDMD), phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu) and manganese (Mn) are presented in Table 4. Season, area and the interaction of season and area (except for two cases of P and Mg) were significant sources of variation ($P \leq 0.05$). Differences between times of sampling were consistently non-significant for any of the variables. Differences among grazing orbits and cows showed no consistent trend. The interaction of time by season was significant ($P<0.05$) for CP only.

Table 3. Least squares means of nutritional values of Maasai cattle diet.

	N	CP %	NDF %	IVDMD %	P[1] %	Ca %	Mg %	Fe ppm	Cu ppm	Mn ppm
Overall mean	126	8.1	69	49	0.26	0.5	0.22	1703	6.2	67
<u>Season</u>										
Feb/Mar'83 Green/ dry = 5	33	8.1^{a}	68^{a}	50^{a}	0.26	0.4^{a}	0.23^{a}	1637^{a}	6.5^{a}	116^{a}
May/June'83 Green = 6	45	10.7^{b}	68^{a}	53^{b}	0.26	0.6^{b}	0.27^{b}	1122^{b}	6.4^{a}	38^{b}
Sept/Oct'83 Dry = 9	48	5.5^{c}	71^{b}	45^{c}	0.27	0.5^{c}	0.17^{c}	2351^{c}	5.6^{c}	48^{c}
<u>Area</u>										
Kavati	21	10.1^{a}	70^{a}	51^{a}	0.31^{a}	0.5^{a}	0.23^{a}	2214^{a}	7.4^{a}	89^{a}
Olkarkar	26	8.8^{b}	68^{bc}	51^{a}	0.26^{b}	0.4^{b}	0.21^{ab}	2002^{a}	6.3^{b}	73^{b}
Ilkelunyeti	21	7.7^{c}	70^{a}	47^{b}	0.24^{c}	0.5^{a}	0.24^{a}	1536^{b}	5.4^{c}	58^{c}
Oiti	31	7.1^{d}	67^{b}	51^{a}	0.28^{b}	0.5^{a}	0.20^{b}	1242^{b}	6.0^{bc}	59^{c}
Isupanani	27	6.9^{d}	69^{ac}	48^{b}	0.21^{d}	0.5^{a}	0.24^{a}	1523^{b}	5.8^{c}	58^{c}

abcd Means having no letter in common differ at $P<0.05$.
1 Corrected for saliva.

Table 4. Least squares means of nutritional values of Maasai cattle diet: whole sample, leaves, and stems and sheaths.

Variable	N	CP	NDF	IVDMD	P	Ca	Mg	Fe	Cu	Mn
WS	126	8.1^{a}	69^{a}	49^{a}	0.26^{a}	0.5^{a}	0.22^{a}	1651^{a}	6.2^{a}	67^{a}
L	105	7.8^{b}	70^{b}	50^{a}	0.24^{b}	0.5^{a}	0.20^{b}	1742^{a}	5.9^{a}	63^{a}
SS	104	5.7^{c}	77^{c}	42^{b}	0.18^{c}	0.3^{b}	0.15^{c}	955^{b}	4.5^{b}	53^{b}

abc means having no letter in common differ at $P\leq0.05$.
% = N, CP, NDF, IVDMD, Ca, Mg; ppm = Fe, Cu, Mn.
WS = whole sample; L = leaves; SS = stems and sheaths.

Nutritive Values of Diet Fractions

Least squares means of nutritional values of Maasai cattle forage fractions are presented in Table 5. In all cases the analyses of the whole sample (WS) and leaves (L) were significantly higher than those of stems and sheaths (SS).

The WS was higher than L by 0.3, 1.0, 0.02 and 0.02% in CP, NDF, P and Mg content respectively ($P\leq0.05$). Other differences between WS and L in IVDMD, Ca, Fe, Cu and Mn were not significant ($P>0.05$).

Table 5. Least squares means of nutritional values of Maasai cattle diet: fraction x season.

Season	N	CP	NDF	IVDMD	P	Ca	Mg	Fe	Cu	Mn
<u>Green/dry</u>										
WS	33	8.2^a	68^a	50^a	0.26^a	0.4^a	0.23^a	1434^a	6.4^a	114^a
Leaf	33	7.5^b	69^a	49^b	0.23^b	0.5^b	0.21^a	1767^a	6.0^a	98^b
SS	28	5.9^c	76^b	42^c	0.19^c	0.3^c	0.18^b	681^b	4.8^b	71^c
<u>Green</u>										
WS	45	10.6^a	68^a	54^a	0.26^a	0.6^a	0.27^a	1097	6.4^a	38
Leaf	40	10.0^a	71^b	54^a	0.23^b	0.6^a	0.23^b	1089	6.3^a	42
SS	37	6.8^b	78^c	46^b	0.14^c	0.3^b	0.16^c	808	5.2^b	39
<u>Dry</u>										
WS	48	5.6^a	71^a	44^a	0.27^a	0.5^a	0.17^a	2421^a	5.7^a	47
Leaf	36	5.9^a	71^a	46^b	0.25^a	0.5^a	0.17^a	2370^a	5.2^a	49
SS	39	4.4^b	78^c	38^c	0.20^b	0.3^b	0.11^b	1375^b	3.4^b	48

WS = whole sample.
SS = stems and sheaths.
abc = means within the same season having no letter in common differ at $P \leq 0.05$.
% = N, CP, NDF, IVDMD, P, Ca, Mg, PPM = Fe, Cu, Mn.
1 = corrected.

The L fraction exceeded SS nutritively by 2.1, 7, 8, 0.06, 0.2 and 0.05%, 787, 1.4 and 10 ppm or by 26, 10, 16, 23, 40, 23, 48, 23 and 15% for WS in CP, NDF, IVDMD, P, Ca Mg, Fe, Cu and Mn respectively.

For the seasons represented, the Fe concentration followed a different trend from the other elements for the green season, as differences between the fractions were not significant ($P>0.05$). The peculiar trend for the green season was probably because the Fe analysed in plant fractions was partly endogenous and partly exogenous arising from soil contamination and came from dust and soil ingestion during grazing; the green season dust was minimal and cattle did graze close enough to the ground to ingest soil or dust. In all seasons the SS fraction had the lowest concentration of Fe due to its smaller surface area on which dust could land.

DISCUSSION

In the normal seasons of 1983 three grass species dominated. The three species, *Digitaria macroblephara, Chloris roxburghiana* and *Pennisetum mezianum* were preferred probably by virtue of being perennial, and having greater ground cover than other grass species. For the first two species Kibet (1984) has advanced similar reasons for their selection by cattle. Another stabilizing factor between the seasons' diets was the bimodal rainfall received. In the extreme conditions that prevailed in the drought of 1984 changes were forced in the diet selection.

Cattle selected more of the less palatable and dead grass as litter. For the seasons by area, species composition varied little, but in contrast the quality of the diet was influenced much, due to environmental differences of rainfall, soils and ambient temperatures. The decision of the pastoralists to move their cattle to Kiboko area was wise nutritionally. The cattle browsed more and, presumably, got sufficient N to enhance their utilisation of the litter and the less palatable species that were available.

The mean and the seasonal variation of CP was consistent with what has been reported of clipped and OF samples from Kenya (Karue, 1974; Potter, 1981; Reed, 1983; Tessema and Emojong, 1984). This means the problem of rapid decline in CP is not an isolated case for the Maasai rangelands alone. This is probably explained by the high temperatures in the growing seasons that is characteristic of Kenyan rangelands, which accelerates plant maturation leading to lignification. If protein supplementation is contemplated in these areas, for maximum return, it should be restricted to September/October when the mean value of CP was lowest (5.5%).

The highest value of NDF (73%) obtained in this study is equal to the mean value of Tessama and Emojong (1984) and lower than 79% of Reed (1983) from comparable rangelands. These differences may have occurred due to sampling technique of OF versus clipping.

Digestibility is known to limit voluntary forage intake (Campling *et al.*, 1962; Blaxter and Wilson, 1962; Karue *et al.*, 1973), and within certain limits there is a positive correlation between digestibility and intake. This was shown by Elliot and Fokkema (1961) over a range of digestibilities of forage from 42 to 64%. The digestibility of Maasai cattle forage fell within this range (42-59%), and it may be assumed that their voluntary intake was limited by low digestibility.

Except for Ca and Fe all other elements investigated were only marginally above the critical level. For increased productivity of cattle in this production system serious considerations must be given towards supplementation with mineral salts. For P and Cu, apart from being marginally above the critical value, their availability is hampered by other factors prevalent in the study area. With regards to P, the Ca:P ratio does influence availability and utilization. Ratios of Ca:P of above 2:1 could limit availability and utilization of P (Conrad *et al.*, 1982) and such ratios were observed in certain seasons and areas of the present study. On the other hand Cu requirements for livestock increases where Mo concentrations in the diets is high. In the study area Mo is high as reported by Whittington and Ward (1983). This implies there is need for Cu supplementation in order to cover the shortfall from marginal concentration in the forage and extra requirements triggered by excessive concentration of Mo.

Differences in the nutritive values of the L and SS fractions were large, and the diets were made-up of 80 to 89% L. This means cattle selected the most nutritive parts of the forage available. Thus when OF samples and clipped samples are taken at the same, time the former commonly exceeds the latter in nutritive value (Pratchett *et al.*, 1977; Holechek *et al.*, 1982). However, the nutritive edge of WS over L was unexpected, because the former contained SS fraction which had the lowest values. These results must have been influenced by the high content of L in WS. However, the edge in the nutritive value of WS over L was probably due to the fact that the most nutritive part of a plant at any time is the growing point be it stem or leaf. As the growing points of the stems and sheaths were part of the WS, they contributed positively to its nutritive value. The same happened to the SS fraction, but due to its greater proportion of senescent stems and sheaths, the growing points contribution was insignificant. Lambourne and Reardon (1962) reported the digestibility of stem was initially higher than that of leaf but falling more rapidly after ear emergence. So the longer any part of the plant, in this case grass, remains in the growing stage, the better. Wilson (1983) cited 24 authors whose work showed that when herbage was stressed by lack of water, digestibility either increased or showed no change. Moisture stress slows growth and hence delays senescence.

CONCLUSIONS

Forage intake by Maasai cattle was limited in the dry seasons by low values of crude protein and dry matter digestibility and high values of neutral detergent fibre. In addition to the low nutritional value of the diet being a limiting factor to intake, the dry seasons were characterized by scarcity of forage on offer.

Supplementation with phosphorus, magnesium and copper is recommended during the dry seasons because of low forage intake. In green seasons supplementation is not necessary at the current production level of the cattle. On the other hand iron level in the diet was extremely high. As this high level (of over 300% above the recommended level) could be toxic, there is need for investigations on its effect and its interaction with other elements.

Digitaria macroblephara and *Chloris roxburghiana* contributed greatly to the diet of Maasai cattle. Due to the fact that they are perennials of high palatability, drought resistance and nutritive value, they are ideal species for either introduction or re-seeding in arid and semi-arid areas.

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LIVESTOCK FEEDING POTENTIALS, CONSTRAINTS AND POSSIBLE IMPROVEMENTS IN THE SEMI-ARID AREAS OF CENTRAL TANZANIA

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Abstract

Based on a diagnostic survey carried out in Mpwapwa District, the main features of the farming system are presented. This is followed by a description of the grazing lands which supply the major feed component of the ruminant population. The existing grazing pattern and farmer feeding strategies over the seasons are discussed.

The farmers are agropastoralists producing mainly for subsistence. Livestock sales is the main source of cash income which in turn is spent on purchase of grain. There are very low investments in agricultural production resulting in low production coefficients.

Despite the uneven distribution and poor quality of feed resource, farmers do manage to take most of their stock through the dry season by employing various strategic measures. Loose grazing of animals in the crop fields after harvest is the main form of supplementation (60% of the respondent n = 152). However, it is evident that poor animal nutrition in the dry season is a serious problem in the livestock production subsystem. The causes of the problem are discussed and research opportunities are highlighted.

INTRODUCTION

Central Tanzania covers an area of 140,000 km^2 in the central semi-arid plateau, between latitudes 4° and 7°S and longitudes 33° and 37°E (Figure 1). The plateau lies at an elevation of 750-1500 m, the eastern boundaries of which are steeper escarpments rising to 1750 m above sea level. The area has a dry savannah type of climate with a long dry season between April and November, and a short wet season from November to April (Figure 2). The total annual rainfall ranges between 250 mm to 750 mm with an average of 600 mm. The distribution is very erratic and reliability is low. Average temperatures are 20-25°C with a diurnal range of 12°C. Apart from the extensive areas of alluvium the two main soil types are a greyish sandy and red sandy loam textured. Severe leaching and laterisation are a common feature of the area. Natural vegetation consists of a dense deciduous thicket with *Commiphora* and *Acacia* as the dominant genera.

Typical of semi-arid areas most of the land is of marginal agricultural productivity with the exception of small pockets of high potential along the eastern boundaries. The dwellers are agro-pastoralists integrating crop production and livestock

Figure 1. Central zone of Tanzania (Singida and Dodoma regions).

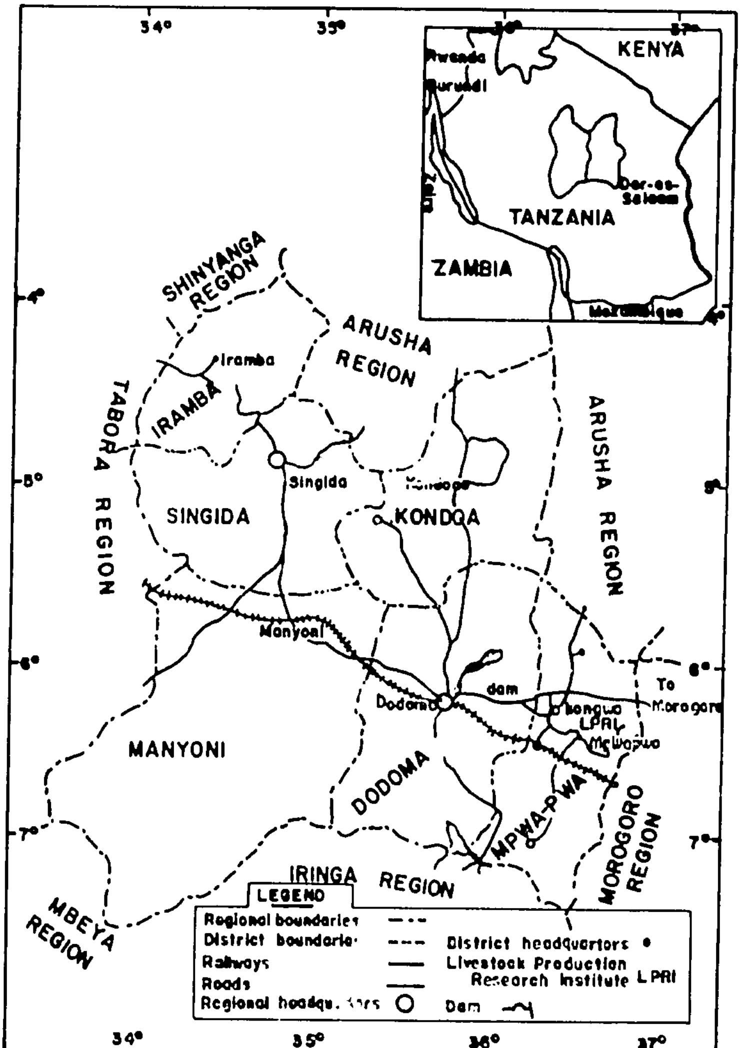
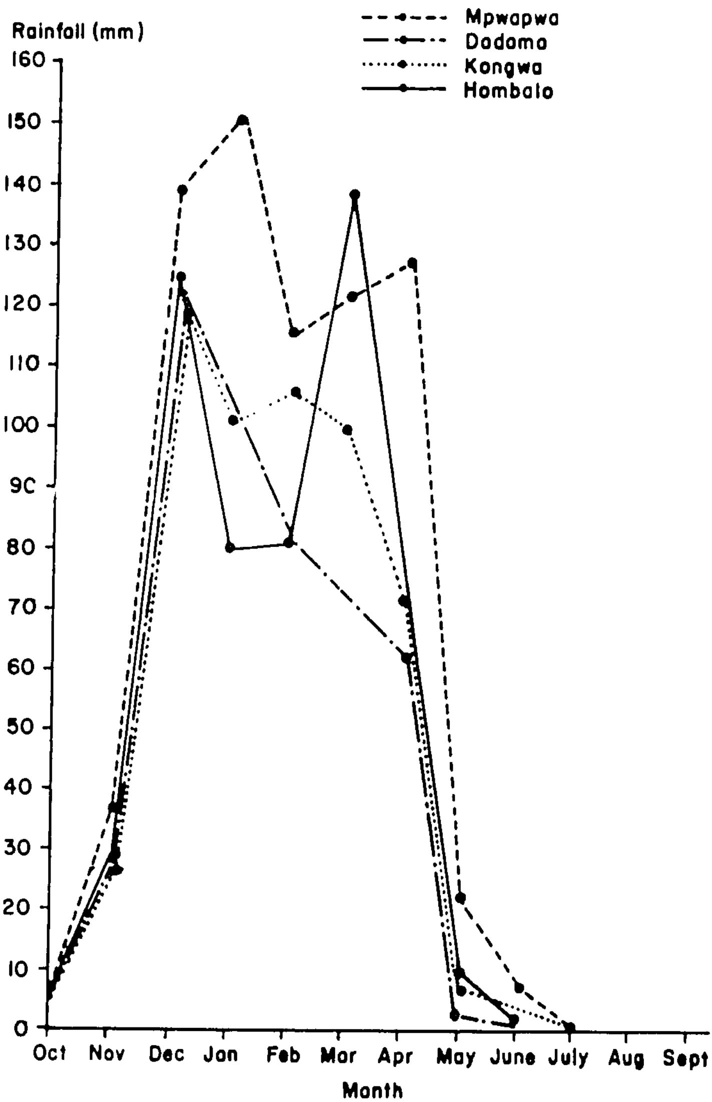


Figure 2. Average rainfall distribution (1974-1984), Dodoma region.



tractors and draft power respectively in the previous cropping season. Agricultural production was mainly for subsistence. Seven percent of the respondents said they would sell their surplus yields, and the main source of cash income for the majority (79%) was livestock sales. Hence, food ranked first (35%) in the expenditure list, followed by clothing (32%) and crop farming (18%).

The livestock species kept were cattle, goats, sheep, donkeys, pigs and poultry. On average one farmer kept 38 head of cattle, 18 goats, 7 sheep, 4 donkeys and 17 chickens. The cattle kept had been acquired through inheritance, exchange of smallstock with grain, dowry or direct purchasing. There were high variations in herd sizes across the area, the majority (76%) having between 10 and 60 head of cattle. The herd sizes declared by the farmers were lower than those reported in the literature and from general observation. The discrepancies may have been due to the well known reluctance of pastoralists to reveal such information to strangers.

Grazing Lands and Feeding Strategy

Herding is the main method of supplying feed for the ruminant population in the study area. The operation is carried out by adult male members of the household. It was evident that herding is a well-planned activity among the livestock keepers. Some farmers indicated herding their animals collectively while others did it individually. In most cases there is strategic herding to combat cattle rustling which was indicated to be a common problem among the livestock keepers (72% n = 152).

Describing the grazing lands of the study area can be quite difficult for researchers. For instance, there were no clear cut boundaries between the cropping land and the grazing lands. Moreover, after crop harvest the crop fields turn into grazing lands. The herdsmen, however, could identify their specific grazing areas, and grazing in crop fields was considered to be feed supplementation. Follow-up observation on the grazing pattern revealed that the individual or group herds were grazed in specific areas. Grazing times are determined by the herdsmen, basing it on the animal behaviour. Discussion with the herdsmen revealed that they had a good knowledge of the rangeland, could tell the most palatable species and that the choice of grazing areas was based on their knowledge and experience.

The main grazing lands are in the secondary thicket which is an open community that has invaded abandoned crop land as a consequence of the shifting cultivation common in the area. It is composed of a mixed association of grass species and herbs. The common grass species were: *Urochloa trichopus, Dactyloctenium* sp., *Aristida* sp., *Eragrostis* sp. and *Chloris virgata*. Perennial grass species found in isolated areas were: *Cynodon* sp., *Cenchrus* sp., *Hyparrhenia* sp. and *Panicum* sp. Identified annual herbs included *Astripomoea* sp., *Crotalaria* sp., *Commelina* sp., *Cleome* sp. and *Ipomea* sp. The common perennial weeds were: *Solanum pandoroeforme, Sida grewiodes* and *Tephrosia incana* while common thicket species were *Cassia* sp., *Croton* sp. and *Acacia* sp. Most of the vegetation including weeds and shrubs were readily eaten by all classes of stock, a feature common in most semi-arid areas (Dyne *et al.*, 1984).

The common grass species are generally known for their low nutritive value. Work done by Karue (1974) indicated that most of the grass species cannot meet the nutrient requirement of the ruminant animals. He deduced that even the best of grasses notably *Cynodon dactylon* and *Digitaria setivala* could only supply about 30% of the protein required by the beef animal. This can lead one to conclude that the shrubs, weeds and other forage play a big role in the nutrition of the animals. In recognition of this, herdsmen cut down branches of browse for easy access to the animals.

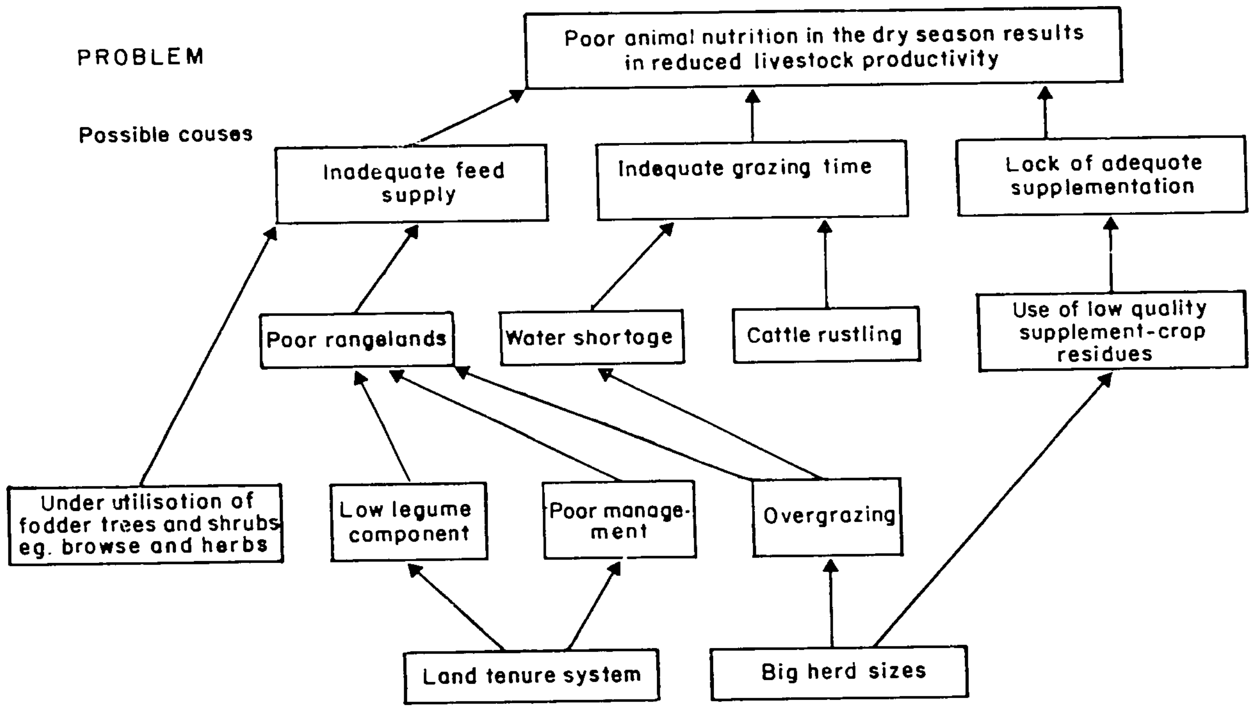
Availability and quality of the feed resource fluctuates during the year between the wet and dry seasons respectively. While in the wet season forage is abundant, in the dry season it is both scanty and poor in quality. Various strategies are adopted by the herdsmen in overcoming feed shortage problems in the dry season. Of main importance is the grazing in the crop fields after the harvest to utilise crop residues. About 60% of the respondents indicated doing so. A smaller proportion (40%) indicated burning; leaving the crop residue in the field and burning it when preparing land for the next growing season. In practice most of the residue is utilised by the animals, for no fencing was observed in the crop fields. Some farmers were reluctant to allow grazing in crop fields allegedly because it would result in reduced crop yield. Collection of crop residues for feeding was not a common practice probably because of limitations of transport.

In summary, crop residues play an invaluable role in dry season for it is only when it is exhausted that herdsmen opt for other strategies. These include movement of animals to distant grazing lands for varying periods depending on the severity of dry periods; this involves a daily trekking of animals to distances as long as 6 km or more in search of pastures and water.

RESEARCH OPPORTUNITIES

Poor animal nutrition particularly in the dry season came out as one of the major constraints to livestock productivity in the study area. This view is supported by the low milk production in the dry season. Whereas, 1.4 litre per cow per day could be produced in the wet season, milk production in the dry season was negligible. The slow growth rates leading to attainment of mature weights in seven years could partly be due to poor nutrition also. Furthermore, movement of animals to distant grazing areas in the dry season results from the feed shortages. This problem can be described with the causes shown in ovals diagrammatically (Figure 3). There can be many causes to this problem and some of the causes are interrelated. Three major causes to the problem have been identified in the current study: inadequate feed supply, inadequate grazing time and lack of adequate supplementation.

Figure 3. Diagrammatic representation of poor animal nutrition.



The main causes could be further analysed to the root causes which can be used to identify research opportunities. Some of these could be difficult for researchers, for instance the big herd sizes, the land tenure system, cattle rustling and water shortage. These would require a closer relationship between researchers, policy makers and other national development agencies. On water shortage, improvement of the environment through afforestation programmes and use of water harvesting technologies could alleviate the problem. Water conserving fruits e.g. watermelons are being used by some farmers for feeding sensitive classes e.g. calves and sicklings. Wider use of these could also reduce the problem but this has to be directed to specific classes depending on production targets.

Various techniques for improving rangelands have been suggested and some tested by range scientists. However, as Nestel *et al.*, (1973) correctly puts it, "the major constraint lies in introducing change into the existing socio-economic systems, exacerbated by inexperience in adopting technology to suit local conditions". Exploitation of fodder trees and shrubs might involve introduction of more drought resistant and high quality species. The FSR team working on the research area is trying to introduce browse spp. such as *Desmanthus virgatus, Leucaena leucocephala, Sesbania sesban, Sesbania spinosa* and *Rhynchosia senaarensis*. However, a parallel comparative study of the nutritive value of the indigenous and introduced browse species is worthwhile for the former is already adapted. Information on the potential of the browse spp. as a forage resource in the area is scanty and most of the research work on this has not been conclusive (Kabatange *et al.*, 1984). Its establishment might raise some problems because of the existing land tenure system. Furthermore, to introduce these as fodder banks might involve transportation which will again require wider use of draught power. As noted earlier, the use of draught power was not common particularly for the Gogo ethnic group who own the largest proportion of the cattle. Compassion is the main latent reason for not using animals for draught power.

Improvement of the natural rangelands by introduction of drought resistant better quality grass genera such as *Cenchrus* and *Cynodon* would be a good alternative, but the problem of land tenure would limit its success. However, such introductions could be effected in the terminal year of cropping before the farm is left fallow Another alternative is to improve the nutritive value of crop residues with minimal investment. This has been a subject of discussion (with ILCA scientists probably leading the way), and a number of field experiments have given positive results (Butterworth and Mosi, 1986; Saleem, 1985). These experiments have been based on inclusion of annual legumes in the crop fields. Of importance to consider here is the time to undersow the legume in relation to grain yield and farmer labour requirements.

The main grain legume in the study area was groundnuts. This legume is harvested earlier than the cereal, and the method of harvesting i.e. uprooting the whole plant, does not make it a good legume for consideration. Furthermore, since the crop is harvested when the shoot is green and it is piled up, in most cases it gets mouldy and might not be a good supplement. Other common legumes grown in the area are cowpea and *Lablab* spp. Since the leaves of cowpeas are used as a vegetable, *Lablab* spp. remain the best alternative. Thus, inclusion of this legume in the cropping systems and its effect on crop yield, quality of stover and livestock productivity could be investigated.

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THE POTENTIAL OF PASTURE LEGUMES AND THEIR ROLE IN IMPROVING FARMING PRACTICES UNDER EXTENSIVE LIVESTOCK PRODUCTION SYSTEMS IN ZAMBIA

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Abstract

The development of improved pastures in Zambia is reviewed on the basis of research and farmer experiences. Pasture research programmes have provided much basic information about development of pasture systems for both dairy and beef cattle. There is need to know much more about how to maintain stable pastures, the persistence of legumes, establishment of improved species, maintenance fertilizer requirements and pasture management; more information is needed on the economic aspects of these systems. To increase production with minimal increase in costs seems possible only with an integrated usage of improved and native pastures.

INTRODUCTION

The most important constraints to improving livestock production in Zambia are related to animal nutrition. The feed resources mainly based on the natural pastures, are poorly managed throughout the country. Due to the long dry season, there are feed shortages so that animals lose weight, suffer high death losses and exhibit low fertility. When animals are under so much stress, they are also more susceptible to diseases. Overstocking and overgrazing, which are very common in many grazing areas in Zambia, have resulted in serious land degradation, the disappearance of valuable pasture species and the spread of unpalatable species. When natural veld pastures are developed with a legume-base and fertilized mainly with superphosphate, most of them can yield large quantities of low-cost animal products. Legumes supply nitrogen cheaply for the associate grasses and grazing ruminants, and their large scale use in the future will ensure that adequate quantities of beef and milk will be within the financial reach of the rapidly expanding population of Zambia.

In many areas of Central, Southern and Lusaka provinces in Zambia, inorganic nitrogen-grass systems are used for dairying and intensive beef production, but with increasing costs and the removal of subsidy and possible shortages of energy, there has been created a potential instability in price/supply of fertilizer N, thus making this practice uneconomical. There is, therefore, a swing in these areas to legume-grass systems.

One of the most important facets of tropical pasture research is to find legumes suitable to the Zambian environment. Pastures based on these legumes have the potential for both higher stocking rates and faster cattle growth rates which can result in a significant increase in animal production.

PAST AND PRESENT SITUATION

The volume of pasture research, and hence of literature, on the improvement of pasture production in Zambia, is very great, and no attempt is made here to review it fully. There have been other reviews by Prins (1970), Craufurd (1979), Kulich and Kaluba (1985), Kulich (1985), Kulich and Nambayo (1985), and Kulich (1986). During the past 30 years there have been significant contributions on pasture legume research notably by Smith (1962, 1963), van Rensburg (1967, 1969a, 1969b), Potter (1972), Verdoom (1965), Prins (1972, 1975), Peterson (1975), Shalwindi (1978), Craufurd (1978), ?. and S. Kulich (1973, 1976) and by Kulich (1977, 1981). Despite the efforts of these people to stimulate commercial interest, farmers have not responded in any significant way.

During the '50s and early '60s beef production was not particularly profitable; the beef enterprise played second fiddle to tobacco and maize. Although farmers were planting pasture grasses, they were not prepared to spend money on the more expensive legumes. In the '70s, the situation started to change with an increase in consumer demand coupled with the banning of beef imports. When beef became more profitable there was increasing interest in pasture development. This interest, however, was not matched with a corresponding interest by most farmers with pasture legumes. The farmers relied on inorganic nitrogen which was heavily subsidised. As costs of N fertilizer increased with removal of subsidy in the 80s interest in pasture legumes was renewed and a high research priority was given aimed at finding stable legume-grass systems. There was an increased emphasis on pasture seed production as a result.

Locations

The investigations were carried out at two locations:

1. Mount Makulu Research Station, situated 16 km south of Lusaka at an altitude of 1,206 m. The average annual rainfall at this site is about 803 mm, falling during the rainy season that spans the November-March period. The mean annual temperature is 20.7°C with the coldest months, June and July, experiencing occasional ground frosts.

2. Chimyamauni Farm, Mkushi, situated 300 km north of Lusaka at an altitude of 1,300 m. This site has an average annual rainfall of 900 mm and a mean annual temperature of 19.8°C.

RESULTS AND DISCUSSION

Excellent results have been obtained from three pasture legumes: Siratro, Stylo and Glycine at Mount Makulu. They have been grown in pure stands and in pasture mixtures for a number of years, and their suitability has been well established. For instance, two-year-old *Chloris gayana* (Giant Rhodes grass) was oversown with *Macroptilium atropurpureum* (cv Siratro), *Stylosanthes guianensis* (Stylo) and *Neonotonia wightii* (Glycine). The pasture received a fertilizer application of 400 kg/ha of single superphosphate and 200 kg/ha of muriate of potash. All three legumes developed satisfactorily and formed a considerable proportion of the total herbage as demonstrated in Table 1.

Table 1. Herbage yield from Rhodes grass/legume pastures.

Pastures mixtures	July	January			Legume as percent
	kg DM/ha	kg DM/ha grass	kg DM/ha legume	kg DM/ha total	of total
Rhodes grass/Glycine	1,307	771	144	915	15.7
Rhodes grass/Siratro	1,840	1,442	260	1,702	15.3
Rhodes grass/Stylo	1,743	1,504	96	1,600	6.0

Glycine and Siratro recovered rapidly on a section that was burnt accidentally in May. Stylo suffered most from the burning and the plants were subsequently damaged by termites. Siratro spread evenly in a very striking manner throughout the plots producing the most satisfactory and vigorous growth.

All three species were compatible in Rhodes grass/legume pastures and were observed even to grow well with Star grass and in natural pasture swards. In the latter case, establishment and development were relatively small. The legumes were capable of producing well over 6,000 kg/DM/ha and over 1,000 kg CP/ha (16.6% CP). They produced high-quality herbage throughout the season with crude protein values ranging from approximately 10 to 20% generally two to three times higher than the value for grasses. Glycine and Siratro also produced a considerable amount of dry-season growth and yielded 500 to over 1,000 kg DM/ha between June and October when good-quality forage is generally very scarce. These legumes stood up very well to heavy intensive stocking when they were allowed adequate rest between grazing cycles.

Rhodes grass and native grass oversown to legume and stocked at 0.50 to 0.75 ha/steer supported steers for about seven to nine months. The steers gained 90 to 100 kg during the dry period. Glycine and Siratro are fire-tolerant and produce new growth soon after burning. Where they were completely burnt in June, the two species produced vigorous dry-season growth, yielding about 1,160 kg DM/ha. Stylo which is more drought-resistant is not fire-tolerant. The roots are readily killed by burning. It will, however, grow and re-establish itself during the rainy season following the fire from fallen seed.

The above-ground herbage of all three species is killed by frost, but their root-stock is frost-tolerant. Both Glycine and Siratro produced vigorous new growth soon after severe frost which occurred in July, and they continued to produce excellent growth throughout the rest of the dry season. Regrowth of Stylo on the other hand seemed slower.

On loamy soils of medium and heavy texture the most suitable species are Glycine and Siratro, while on the light-textured sandy soils Siratro and Stylo seem to be more suitable. Other cultivated and indigenous species such as Silverleaf desmodium, *Macrotyloma* and *Rhynchosia*, can also play an important role in pasture and forage improvement.

Prior to 1974, large areas in the Mkushi District had been sown to both Rhodes grass and Star grass and some farmers had experimented with Torpedo grass (*Panicum repens*) in their 'dambos'. As a result of the increased profitability of beef, one farmer between 1979 and 1982 was able to clear 600 hectares of land along Mkushi River. The whole area was cleanly wind rowed and ploughed. Grass seed (Rhodes grass, Signal grass and Green panic) was sown with the legumes (Silverleaf desmodium, Greenleaf desmodium, Stylo cvs. Cook, Endeavour, Graham, and Seca, Lotononis and Siratro) into a rough seedbed and lightly harrowed.

In the 'dambos' the area was disced during the dry season. Torpedo grass was planted vegetatively on a metre square spacing and *Lotononis* oversown into the rough seedbed. Since establishment, paddocks have been grazed at an overall average stocking rate of about 1.6 LU/ha. The pastures were heavily grazed during the December to February period and then either rested or lightly grazed for the next three to four months. In the latter part of the dry season they were again subjected to heavy grazing. Results of this exercise are presented in Table 2.

In all cases the legumes were slow to establish although the companion grasses did well. Greenleaf desmodium started well but was quickly grazed out. The Silverleaf desmodium was the most encouraging, quickly establishing itself after the first year and maintaining or even increasing its share of the sward over the following four to five year period.

Of the *Stylosanthes* spp. both Cook and Endeavour did well, but they suffered from termite attack during the last two years. In the rainy season of 1984/85 for the first time in Zambia the incidence of *Anthracnose* was confirmed. Worst affected were the cvs Endeavour and Cook in Rhodes grass. The one stand of cv Graham looked most promising having increased steadily over four years. It seemed less affected by termites and devoid of *Anthracnose*.

The one plot of cv Seca (*Stylosanthes scabra*) started very slowly but had increased steadily despite being heavily frosted in 1981 and 1982. Seca plants spread into adjacent pastures, presumably through dung of grazing animals. The *Lotononis* had done exceptionally well in conjunction with Torpedo grass in the 'dambo'. Because of its palatability, it tended to be very heavily grazed in the dry months, but despite this it still managed to maintain itself.

CONCLUSIONS

It has been proved during the last decade that many of the common pasture legumes will grow in Lusaka, Central and Southern provinces in Zambia. A good balanced pasture should contain both twining and bush-type legumes. The former group is represented

Table 2. Pasture legume establishment at Chimyamauni Farm, Mkushi, Zambia in 1979-1982.

Legume	Area ha	Year of establishment	Companion grass	Estimate of % legume in sward 1980	1981	1982	1983	1984	1985
Greenleaf desmodium	80	2/1979	Rhodes grass	7	15	8	5	3	2
Silverleaf	80	2/1979	Rhodes grass	2	10	12	14	15	16
Cook Stylo	80	2/1979	Rhodes grass	3	15	25	20	18	15
Endeavour Stylo	80	2/1979	Rhodes grass	3	13	18	12	10	7
Lotononis	80	2/1979	Rhodes grass	-	1	2	3	4	5
Silverleaf desmodium	20	1/1980	Rhodes grass	-	5	11	20	25	23
Siratro	20	1/1980	Rhodes grass	-	4	12	15	15	15
Cook Stylo	20	1/1980	Rhodes grass	-	4	10	37	30	25
Seca Stylo	10	1/1980	Rhodes grass	-	18	35	48	50	
Lotononis	4	1/1980	Torpedo grass	-	15	30	40	45	45
Silverleaf desmodium	10	2/1980	Signal grass	-	5	12	18	25	40
Lotononis	6	1/1981	Torpedo grass	-	-	20	35	45	40
Greenleaf desmodium	60	2/1981	Rhodes grass	-	7	18	20	10	8
Graham Stylo	20	1/1982	Signal grass	-	-	10	14	20	25

by Silverleaf desmodium and Siratro while Seca and Graham Stylos are the most promising of the latter group. Lotononis continues to be the main hope for 'dambo' improvement. There is no point in growing grass and legume pastures unless they can be properly utilised. It is likely that they would grow and thrive well if they are adequately managed. If pastures are allowed to grow unchecked during the entire growing season, the herbage becomes mature and coarse, and it rapidly deteriorates in feeding value. Pastures which are subjected to intensive rotational grazing remain relatively green and leafy and improve in basal cover. The major constraint to the expansion of legume/grass pastures is availability of seed. The seed production programme is being carried out under the auspices of the Government of Zambia and the Swedish International Development Authority, Agriculture Sector Support Programme. This programme has demonstrated the potential that there is for local seed production of different kinds of pasture species if a good management and good permanent maintenance breeding programme is introduced.

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LAND-USE CHANGES IN RANCHES WHICH WERE SET UP IN MARGINAL AREAS OF KENYA

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Abstract

A number of ranches were set up in marginal areas during colonial days, and they were the main source of steers for the beef market. Most of these ranches were bought by local people after forming cooperative societies. These ranches are being subdivided by the society members for dry land farming.

This may lead to a drop in beef production and without proper land-use planning, may lead to soil erosion. Already an area east of Lake Naivasha is experiencing wind erosion during low rainfall seasons. Once the land-use has changed from ranching to crop production, the people in range management should move out of the area and concentrate in semi-arid areas where livestock production should be intensified.

INTRODUCTION

The British colonial settlers established excellent commercial ranches, mainly in Machakos, Nakuru and Laikipia districts. After independence most of the white settlers offered their ranches for sale to Africans. The sale prices for those ranches were so high that Africans could not raise the required money at that time. Loans were made available at 80% of the sale price.

The local people decided to form cooperative societies whereby each member was to raise Shs. 2,000/= to buy one share. Some members still could not raise the Shs. 2,000/= and had to incorporate other members. Thus one share was bought by a number of people but only one of them had his name registered. The others were called shadow members. For some time the high quality standard of livestock was maintained and a number of the ranches supplied the local farmers with improved bulls. The Kenya Meat Commission also continued to get high grade steers for slaughter.

The current study was carried out to determine the effect of subdivision to livestock development and ecology of the range.

COOPERATIVE RANCHING SOCIETIES

A cooperative ranching society is where members own a ranch through the purchase of shares. A general meeting is held once to elect a committee of ten who run the ranch on behalf of the members. A general manager, who is supposed to know livestock husbandry, is recruited by the committee.

When shareholders bought the ranches most of them thought that the benefits coming from the ranch would be immediate and substantial. Others became members just to see the colonialists go, while still others thought they would graze their own livestock side by side with the society ones.

Most of the societies started experiencing problems brought by members. Committee members were the worst. Some of them took money from non-members then allowed them to graze their cattle on the society's land, while other members brought their relatives to live in the ranch as squatters. Some of the white settlers promised their workers part of the ranch when it was sold. This made employees become squatters in some ranches. A case in point is Kiu Co-operative Ranch where workers occupied 4000 acres since 1971 when the ranch was sold. The biggest problem to the societies, especially those in Machakos District, came from shadow members. These members were not allowed to participate in annual general meetings. Whenever a dividend was declared, it was paid only to registered members. The shadow members became a force which was soon recognised by the Government. They were later allowed to become members by increasing their share contribution.

Cooperative Ranches in Machakos District

By 1964 local people in Machakos had formed 55 cooperative societies. Some of the ranch societies in the district are listed in Table 1. The problem with shadow members was experienced in Machakos only. Some committee members were illiterate, so instead of guiding the general member, they retarded his development plans. Some of the managers were not fit for the posts as their employment was influenced by some committee members. Because of all these problems it became necessary to subdivide the ranches.

Table 1. Cooperative ranching societies in Machakos District.

Name	Size (acres)	Date began	Original member	Land area per member in acres
Katelembo	11,954	1972	3446	3.5
Kiu	11,330	1971	994	11.4
Nguu	34,000	1967	1600	21.3
Konza	35,658	1964	1604	22.2
Kima	9,108	1973	1604	5.7
Lukenya	60,000	1963	743	80.8
Drumvalle	11,330	1964	1462	7.7
Mountain View	1	1967	1462	1
Koma-Rock	36,190	1963	279	129.7
Katheka-Kai	16,945	1971	188	90.1
Kalembwani	5,085		854	
Aimi Ma Kilungu	35,425		1422	24.9

Table 2 shows the members' plot sizes after subdivision. Officers in range management have always tried to stop the subdivision of the ranches because they anticipate land degradation and reduced livestock numbers in the whole country.

Table 2. Effects of subdivision on livestock production under cooperative management.

Ranch	Acreage	Members	198[illegible]
Konza	35,658	3,546	841
Katelembo	11,954	932	467
Kiu	11,330	1,407	955
Katheka-Kai "B"	16,945	1,124	1,061
"A"		246	
Nguu	34,000	3,309	2,096
Lukenya	60,000	4,042	3,460
Koma Rock	36,190	2,595	197

IMPLICATION OF SUBDIVISION

The effect of subdivision is already being felt in the country.

Kenya Meat Commission

During colonial days KMC made arrangements with the ranchers on the sale of finished steers for slaughter. Ranchers finished their steers with a market already assured while KMC officials also made all their purchases by telephone. KMC was thus able to operate at its full capacity.

As these ranches changed hands and subdivision started, sale by telephone came to an end and KMC is almost closing its two factories in Mombasa and Athi River near Nairobi because of lack of animals to slaughter.

Land Use Changes

Ranches which are already subdivided are being turned to crop production on subsistence level. Wildlife from Nairobi National Park and Hopecraft Game Ranch graze in these ranches during dry season. There will be continued crop damage by wildlife.

Land Degradation

An area east of Lake Naivasha called Mai Mahiu which had been subdivided much earlier and whose members are growing maize and beans is being degraded through erosion. Members harvest crops successfully once in five years. Wind erosion becomes serious when rains fail to come after land has been prepared.

Shortage of Steers for Slaughter

Most of the trained range management officers look upon pastoral areas (especially those in ecological zones V and VI) as being difficult areas. No proper cattle sales are organised and instead there is permanent quarantine over cattle movement because of contagious Bovine Pleuropneumonia. Thus there are no plans for improvement regarding such problems.

POSSIBLE SOLUTION

Improved Livestock Feed

Most of the vast beef production areas in Kenya fall under ecological zones V and VI, where rainfall is erratic and the larger part of the year is dry. Livestock spend most of their time feeding on dry and protein-deficient forage. Some research should be carried out to find either deep-rooted legumes or annuals which will grow within a short time and dry up with the protein intact. Land preparation should be limited to scratching the top soil just to stop water from carrying the seeds away.

A STRATEGY OF LIVESTOCK RESEARCH ADAPTED TO SEMI-ARID SMALL-SCALE MIXED FARMING SYSTEM - THE KATUMANI EXPERIENCE

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Abstract

The traditional methods used in livestock and pasture research usually involve component approaches such as grazing management and stocking rate studies; dry-matter yields and nutritional value, growth rates and milk production measurements. However, because of the complementary nature of the relationship between these components, an integrated research effort is a mandatory requisite if relevant and applicable innovations are to be generated. This is particularly true for small-scale farms under mixed farming situations.

The livestock and pasture research strategy at the National Dryland Farming Research Station, Katumani adopted the farming systems approach with four hierarchical levels: base-line study of the traditional system; experimentation; subsystem simulation study and on-farm research. This paper discusses the details of the latter two levels including methodologies used and preliminary observations made. The technical innovations being tested in the sub-system simulation study and the on-farm research are designed to encompass a range of alternative technologies that could increase output and improve livestock productivity in small farm systems of semi-arid areas.

INTRODUCTION

Research in livestock and pasture production at the National Dryland Farming Research Station (NDFRS) Katumani, is principally aimed at increasing feed resources of smallholder agricultural systems of semi-arid areas and developing technologies and management systems that would raise livestock production from the subsistence level to a more commercial or a semi-specialised enterprise system. The research programme is carried out at four hierarchical levels: 1) base-line studies of the traditional livestock production system, 2) experimentation, 3) subsystem simulation study and 4) on-farm research.

The base-line study of the traditional farming system included comprehensive farm surveys in different parts of the semi-arid zone in Eastern Kenya in order to describe the existing farming systems and identify the critical constraints faced by farmers of the region (Rukandema *et al.*, 1984; Tessema *et al.*, 1985). These studies showed that traditional farmers of the dryland areas in Eastern Province avert risks by mixed cropping and livestock raising with the aim of achieving self sufficiency in food production. The land tenure in these semi-arid areas is a frcehold system and farm sizes range from 1 to 20 hectares with a mean of 7.5 ha, out of which 2 to 3 hectares are cropped and 4-6 ha are left as natural rangelands. In the cropping subsystem, the principal crop grown is maize, usually intercropped with beans, pigeon peas and cowpeas. In the livestock subsystem, cattle, goats and sheep are kept by almost all farms, usually in numbers that exceed the carrying capacities of the farms. This has resulted in poor livestock productivity (e.g. in cattle, 50% calving rate; 18 months calving interval, 65 kg weaning weight and 450 kg milked yield per year per lactation). The large number of livestock kept is related to the threat of recurrent food shortages due to crop failures on account of erratic and unreliable rainfall patterns. Thus, livestock are the only means of hedging against such crop failures. They serve as savings and to maintain cash liquidity. Their functions as sources of draught power, manure, meat and milk are secondary. Given these circumstances, however, these smallscale farmers attempt to operate rationally and optimally. Given appropriate technologies and the means to implement them, these farmers are quick to change and do raise their productivity considerably.

RESEARCH BACKGROUND

Experimental research has been pursued on a number of areas. Studies of the natural pasture through simple techniques such as selective bush clearing, burning and reseeding have shown that with a bimodal pattern of rainfall, reasonably high dry-matter accumulation of herbage can be achieved allowing higher stocking rates (2-3 ha/LU)[1] than were normally accepted (6 ha/LU) for the dryland areas (Tessema and Emojong, 1984a). Improvement of crop residues utilisation has shown good possibilities to solve dry season feeding problems. The quality of crop residues was improved through physical treatment and supplementation with high protein *Leucaena* and pigeon pea leaves (Tessema and Emojong, 1984b). The economics of milk production was found to be profitable through feeding cultivated fodders such as Napier grass (*Pennisetum purpureum*) and Bana, (*Pennisetum purpureum* x *Pennisetum typhoides*) to crossbred dairy cows (Thairu and Tessema, 1987). Draught Zebu oxen, when properly managed and adequately supplemented, provide sufficient draught power to break the soil and provide good tilth for planting crops before the rains thus making it possible to prepare more land for food and feed production (Tessema and Emojong, 1984c). Such findings were used for developing a set of improved practices that can be brought together and tested as a package.

In the past, research efforts to improve the productivity of small-scale farms have had little success because of the failure to consider an integrated approach as a research strategy. An integrated research approach is even more important for the livestock system than it is for crops. Improved technological alternatives in crop production such as new crop varieties, new rates of seeding and different planting dates may each be effectively adopted individually without substantially requiring

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[1] 1 LU = 250 kg weight

accompanying technologies or affecting other activities on the farm. Innovations in livestock production, however, may not be considered individually or in isolation without due consideration of their effects on other activities of the farm. For example, the adoption of cultivated pasture and fodder crops depends upon the extent to which the activity is conflicting or competing with food crop farming. Cultivated fodder crops could only be economically utilised by livestock that are highly productive and with good genetic potential for such economic traits as milk production. As the genetic potential of the indigenous zebu cattle for milk production is rather low, the use of cultivated fodder crops for increased milk production would at least require the introduction of crossbred dairy cows in the system. Furthermore, for increased milk production from intensively managed pastures to be fully attained, an adequate water supply, proper animal health care and disease control, appropriate housing and shelter are required. Thus, a single innovation, such as the introduction of cultivated fodder crops in the farming system entails the adoption of a multitude of other activities. Therefore, while a step-wise improvement strategy is possible in crop improvement programmes, the livestock production subsystem must have the 'critical mix' of technological alternatives that need to be implemented and studied simultaneously in order to determine relationships, interactions, competitiveness and/or complementarity of innovations.

At NDFRS in Katumani this is being accomplished at two hierarchical levels in a farming systems framework: subsystem simulation study and on-farm research.

SUBSYSTEM SIMULATION STUDY

In this study the most promising technological innovations emanating from component research in livestock and pasture production are brought together and tested under simulated farm conditions at the experiment station, using the average resources available to a typical farmer in terms of land, labour and capital. The objectives of the study are the following:

1. to identify real constraints of the improved livestock production system when compared with the traditional system;

2. to evaluate inputs, outputs and economics of livestock production under specific farming conditions;

3. to formulate new and economically sound technological packages;

4. to determine the competition and complementarity in resource use between the livestock and cropping enterprises.

Design of the Study

An area of land comparable to the average-sized farm (7.5 hectares) was demarcated at the station. Leaving 2.5 hectares for food crop production, the remaining 5 hectares were put under the following improved practices of livestock production:

a) improvement of the natural pasture through selective bush clearing and burning and reseeding with *Stylosanthes scabra*. The purpose is to improve the quality and quantity of dry-matter production and increase carrying capacity;

b) improved utilisation of crop residues for dry season feeding through better collection and storage, treatment and supplementation with *Leucaena leucocephala* and pigeon peas;

c) planting of cultivated leys (Rhodes grass and *Stylosanthes* mixture) and fodder crops (Bana/Bajra[1]/Napier);

d) appropriate feeding of draught oxen during the dry season;

e) the conservation of excess forage as hay and silage;

f) provision of an appropriate stock shed and other facilities for better feeding, water provision and manure collection;

g) maintenance of a systematic disease prevention and control schedule;

h) adjustment of livestock numbers to the available feed resource;

i) introduction of crossbred (Zebu x Friesian) dairy cows with high milk production potential.

The central theme of the package is to increase feed resources and improve the livestock feeding system by intensifying land use and by integrating feed resources so that continuity of feed supply is assured throughout the year. Livestock production is intensified through the introduction of dairying for commercial milk production based on crossbred cows maintained on improved natural pasture, cultivated fodder crops and supplemented with home grown and conserved feedstuffs.

From this subsystem study, data have been collected over a three-year period on pasture and animal production, including productivity of natural and improved pasture, milk production, calf, lamb and kid growth, weight gains and losses in mature stock, disease occurrence and mortality and livestock offtake. Along with livestock production operation all input data are also recorded: i.e. labour needed for various activities and cost prices of all items used.

Inputs and Investments

The initial and annual costs are given in Table 1 and included the following activities:

Bush clearing

The five hectares of bushy grazing land was selectively cleared. Reseeding with Stylo and Rhodes grass using minimum cultivation methods is still under study.

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[1]*Pennisetum typhoides*

Table 1. Estimated cost of inputs.

Activities	Labour min man days	Initial cost	Annual
5.0 ha of bush clearing	60	1500	?
1.0 ha of fodder crops			
- planting	25	625	-
- weeding (2X)	50	1250	625
0.5 ha of fodder legumes			
- planting	10	300	-
- weeding	10	300	300
0.5 ha of grass/ legume ley			
- seed	-	100	-
- planting	10	300	-
- weeding	10	300	300
2.0 ha crop residues collection, transport and storage	20	600	600
Ensilage of 5 tonnes			
- pit digging	30	900	-
- filling	140	4200	4200
Hay making			
- baling per tonne	20	600	

Establishment of grass/legume leys

The grass/legume ley is composed of Rhodes grass and stylo and requires one thorough weeding each season. This forage is grazed or cut and conserved as hay for dry season feeding.

Establishment of fodder grasses (Bana Napier)

The established plot is expected to have a life span of four to five years and would require one weeding each season (short and long rains). The fodder is zero-grazed during the growing season and any excess is ensiled.

Establishment of fodder legume (Leucaena)

The established plot is expected to have a long life span requiring one thorough weeding each season. The fodder is cut and fed to zero-grazed animals both during the growing season and the dry season.

Utilisation of crop residues

Crop residues from maize, pigeon pea and sorghum are collected properly each season and used during the dry season. Various techniques are used to improve the efficiency of their utilisation, i.e. chopping; treating with urea and supplementation with legumes such as *Leucaena* or pigeon pea leaves and stems.

Forage conservation

Silage-making

The forage material used to make silage in this study was obtained from a one-hectare Bana Napier field which is not part of the five hectares assigned to the subsystem unit. To adopt this silage-making technology, it would be necessary to increase the fodder area of the unit (Table 1) from one to two hectares in order to get the bulk required.

Circular pit silos, 3 deep and 2 in diameter containing 5 tonnes of chopped forage material packed properly by continuous manual filling and trampling have been made. The inside of the silo is lined with a polythene sheeting to prevent contamination with soil and help in excluding air.

Although this method of silage-making was part of the package tested in the subsystem study, silage-making at small-scale farms is recommended only as a communal effort as it may not be possible for a farm to have the necessary bulk of forage crops or the necessary family labour force to do the work, nor would it be economical to do it by hired labour. If made on a communal basis, it is assumed that it will also be shared equally among those who contributed in the effort.

Hay-making

This was done using a simple wooden box hand-baler developed at the station and costing KShs. 260/=[1]. Three men can cut and make 10 bales of hay per day each weighing 15 kg on the average.

The following are the purchased investments included in the package:

Ox-cart

A locally made wooden body ox-cart made from an old car axle and wheels and tyres filled with saw dust cost KShs. 2000/-. These carts are made by a small firm called Ndume in Gilgil near Nakuru town.

Hand chopper

A hand-operated chopper for cutting fodder crops and crop residues cost Kshs. 4000/-. This machine is available in Nairobi. To keep animals in reasonable comfort, to eliminate unhygienic situations and to feed and manage them properly and separately, a shed with partitions for dairy cows, oxen, calves and small stock

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[1] One US dollar = 16 KShs.

Livestock shed

was constructed. Locally available materials were used in the construction of the shed. If corrugated iron sheet roofing is used, it can also serve to collect rain water for use by animals. The bulk of water requirement is, however, hauled from a river source using ox-cart and drums. The livestock shed is estimated to cost KShs. 4000/-.

Number and types of livestock

Based on the feed resources developed on the five hectares of land as given in Table 2, the following livestock were kept in productive state throughout the year:

- three crossbred dairy cows (Zebu x Friesian),
- one replacement heifer, and two oxen (indigenous),
- seven sheep and their followers,
- seven goats and their followers.

Table 2. Estimated total fodder resources.

Type of resource	Yield t DM ha[1]	Total t DM
5 ha improved rangelands	2.3	11.5
0.5 ha grass/legume ley	6.0	3.0
1.0 ha planted fodder	7.0	7.0
0.5 ha *Leucaena*	4.0	2.0
2.0 ha crop residues	3.4	3.4
Total resources		26.9

[1] Total yield per annum from two growing seasons.

An in-calf crossbred heifer is generally estimated at approximately KShs. 4500/- when directly purchased. But the crossbred cows can be obtained through artificial insemination of indigenous cows, thus eliminating this high investment cost.

A stocking rate of approximately one livestock unit (250 kg) per hectare of farm holding (7.5 hectares) is achieved while the mixture of livestock kept will meet the farmer's needs for draught power, milk production (for sale and home consumption) and small stock for meat and periodic sale to meet large payments such as school fees, etc.

Labour required

The labour required to carry out the activities of this livestock subsystem is shown in Table 3. The sum total of man-hours required per day amounts to 11.8 hours. Out of these, seven hours are needed for herding, which under real farm situations can be undertaken by 7 to 10-year-old children who go to school only part of the day. Therefore, these hours need not be considered in terms of adult labour force. In the subsystem unit, grazing areas were fenced, thus the labour requirement for grazing was only imputed. The real requirements of labour hours for the livestock activities in terms of adult equivalents were therefore 4.8 hours.

Table 3. Labour requirement for livestock work.

Activities	hrs/day
Milking: 3 cows at 0.3 hrs/cow	1.0
Feeding: cutting, transporting, chopping, feeding	2.7
Cleaning barn and transporting manure	0.6
Watering, hauling water (1 km) in drums by oxcart	0.5
Herding of cattle and smallstock	7.0
Total	11.8

Other expenditures

These include:
- drugs for all animals(= KShs. 980.00),
- mineral and protein supplements (= KShs. 544.00),
- dipping costs(= KShs.760.00).

Outputs

Fodder resources

The total amount of feedstuffs produced is shown in Table 2 and indicated that 27 tonnes of dry matter were potentially available in an average year.

Milk production

The total average lactation yield from three cows over two lactations was 1870 kg per cow without the calf at foot. This was achieved under semi-zero grazing where the cows were grazed on natural pasture during the day and, in the evenings, were offered chopped Napier grass (*ad libitum*) during the growing season and treated maize stover mixed with green *Leucaena* (at 30% of DM intake) during the dry season.

When 500 liters of the milk produced is fed to the calf over a six-months period, 1370 kg of milk per cow is left for sale or home consumption. This is three times the amount produced by the average cow under traditional management. At a current value of milk in the local market of KShs. 3/- per liter, the value of milk offtake from three cows amounted to KShs.12,330 over a 14-month period.

Livestock growth and offtake

Annual average weight changes of all livestock over a three-year period is shown in Table 4 below.

Table 4. Annual liveweight gains of different classes of stock.

Class of animals	ADG (g)	Class of animal	ADG (g)
Cows <3 years old	264	Oxen 5-6 years old	0
Heifers <2 years old	493	Shoats, young 0-5 months	80
Calves 0-12 months	319	Shoats, adults > 5 months	30

The annual offtakes consisted of three lambs weighing an average of 28 kg, with a value of KShs. 672/- (at 8 KShs/kg) and four weaner goats weighing 30 kg with a value of KShs. 1080 (at 9 KShs. liveweight).

Draught power output

The two oxen provided adequate traction power to plough two to three hectares of land each season, before rains started. They also pulled an ox-cart whenever required to draw water or to transport fodder. The opportunity cost of renting a team of oxen to plough one hectare of land in the area is KShs. 550/-.

Manure

A total of 30 tonnes of manure (a compost made of 80% dung and 20% soil and other plant material) was collected yearly from the herd. The monetary value of this manure, according to current sale price is KShs. 2400 (at KShs. 80/= per tonne).

The technological improvements tested in this study certainly required high inputs. But the outputs are also correspondingly high. It is, however, felt that more data would be required to make an appropriate assessment of the profitability of the enterprise. Calving, kidding and lambing intervals; death rates; the rate of decline in yield of established fodder fields; value of replacement heifers sold or kept etc. are some of the vital data that are still required to make a comprehensive assessment. It is estimated that a period of five years would be adequate to make such an assessment.

The existence of strong interactions between crops and livestock in these small-farm systems is well recognised. While the crop subsystem is being studied in a separate simulation programme, the on-farm research programme discussed below is, however, carried out with an integrated multi-disciplinary approach.

ON-FARM RESEARCH

The most promising results from the multi-disciplinary on-station research were used to formulate technological improvements that would appear to increase the productivity of livestock on small-scale farms in semi-arid areas. Preliminary results of the profitability of these improvements when tested as a package under simulated farming systems also appeared to be very promising. The on-farm research programme was therefore designed to test the validity of these technological innovations *under actual farm conditions.*

There are many factors which determine how rapidly a practice will be adopted by small-scale farmers. These include the costs and risks involved, the ignoring of potential returns, the complexity of the practice, the time it takes for better results, the compatability of the practice relative to cultural customs and established pattern of agriculture. Farmers are expected to respond differently to a given economic opportunity depending upon their subjective evaluation of the innovation. The smaller the potential increase in income from a particular recommendation, the more varied the response of different farmers is likely to be. For example, an increase of 10% to 20% in milk yield or in growth rate above the common experience can hardly be distinguished from changes in yields resulting from the usual seasonal or annual fluctuations. Incentives which in the initial stages bring about increases of 100% or more have a much better chance of adoption. Thus, the concept of the on-farm research programme has necessitated a somewhat radical approach, namely the introduction of a commercialised livestock enterprise in small-farm systems.

Smallholder dairying based on crossbred cows maintained almost entirely on well managed forages and pasture grasses and supplemented with home grown and conserved feedstuffs would indeed seem to be a feasible innovation worth extensive on-farm testing. Except for the problems of feed resources and diseases that may limit level of production, the economic aspects of dairying in low potential areas would not be too different from that of the high potential regions when expressed in terms of returns to labour and capital investment. However, a successful dairying enterprise needs to adapt to the cyclical nature of the environment. Therefore a year- round feed supply of sufficient quality needs to be guaranteed.

The feeding of dairy cattle for improved productivity is best achieved by the integration of herbage from natural rangeland, sown pasture, planted fodders and crop residues. Without the combined use of these different feed resources, increased and sustained milk productivity cannot be achieved. In order to attain this objective a change must come about from the present system of keeping livestock as a separate enterprise to that of fully integrating them in the farming system. As soon as farmers accept that grasses and forages need the same care and management of food crops, a transition from livestock keeping for subsistence to that for productive purposes will be effected.

Design of On-Farm Research

The technological innovations are introduced step-by-step into a number of farms representing the main ecological areas, farming systems and size classes. An optimum plan is made to each individual farm, incorporating as many of the recommended technologies as possible. The recommended improvements in pasture and livestock production in particular are those that require the minimum capital input and the maximum use of family labour force. Since the farms selected are being considered as experimental units, a protective mechanism has been built into the on-farm research programme whereby the inputs are provided to the farmer on the basis of loans. The participating farmers are required to repay these loans only after it has been proven that the innovations have contributed substantially to the net income of each farm. Thus, participating farmers are not subjected to unnecessary risks and losses due to the research exercise being carried out on their farms.

On the basis of rainfall and existing farming systems, the study area is divided into three domains encompassing parts of Machakos and Kitui districts. Domains have been identified:

1. Most favourable, 700-800 mm rainfall;
2. Medium favourable, 600-700 mm rainfall;
3. Least favourable, 500-600 mm rainfall.

Farms are grouped according to farm size in small (5 ha), medium (5 to 10 ha) and large (>10 ha).

Two farms from each domain and each class are selected, making a total of 18 farms. Another group of 18 farms within the same domains are selected to serve as controls where only comparative data are collected.

Each farm is surveyed and appropriate technologies are developed for each domain's classes. *Ex ante* analyses are made by computer modelling and simulation to assess potential applicability, input requirements and constraints and outputs. The technical coefficients used for these analyses were generated from the subsystem simulation study discussed above.

The technological packages being tested on the farms are the same four enumerated under the subsystem simulation study. Improvement packages vary according to each domain e.g. dairy cattle for most favourable rainfall zones and dairy goats for drier zones. Farm plans are discussed with farmers and modified to reflect their preferences and willingness to test innovations. Budgeting and sensitivity analysis techniques are used to determine optimal farm plans.

To date, the on-farm research programme has been implemented only on six participating farms. For the six farms, data have been collected on pasture and animal production including production of natural and improved pasture, milk production; calf, lamb and kid growth; weight gains and losses in mature stock; disease occurrences and mortality. Along with livestock production operations, selected input/output data on all farm enterprises are monitored continually to quantify labour, traction and material inputs as well as the returns for various enterprises, and to assess the pressure on farm resources and the levels of risk of different enterprise combinations faced by farmers. The data will be analysed by linear programming, regression equations and variance analysis to evaluate results and identify variables. Cost-benefit analyses will be made to test economic feasibility.

Achievements of applicable results from livestock and pasture research are lengthy and difficult processes. While substantial data are available from the subsystem simulation study, collected over the past three years, data from the six farms on the on-farm research programme are scanty. Preliminary observations of the research approach used, however, show that the researcher is more knowledgeable of the real constraints of the production system and therefore can design more relevant and effective programmes. It seems also that the desired end results of the research efforts can be arrived at in a reasonably shorter period of time.

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LEGUME-BASED CROPPING: A POSSIBLE REMEDY TO LAND TENURE CONSTRAINT TO RUMINANT PRODUCTION IN THE SUBHUMID ZONE OF CENTRAL NIGERIA

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Abstract

There is a critical shortage of crude protein in fallow and range grazing during the dry season in the subhumid zone of Nigeria. Supply shortages and high cost preclude the use of purchased feed and research was directed towards the production of forage legumes.

A package for creating fenced legume pastures ('fodder banks') has been developed, but since most land is owned by cultivators who do not keep cattle, pastoralists have found it difficult to find the necessary land.

Productivity of the pasture is reduced over time by the build-up of soil nitrogen that encourages invasion by nitrophilous grasses, thereby excluding the desired legume species. This build-up can be reduced by periodic cropping with nitrogen-demanding cereals in order to favour legume dominance. The cereals used for this purpose yield better than natural fallow because of the nitrogen and other improvements in the characteristics of the soil.

This situation can be exploited to increase crop/livestock integration even where they are generally practised by different groups; in this case, farmers and pastoralists. The present paper describes a study carried out to test the hypothesis that legume-based cropping is beneficial.

INTRODUCTION

The ILCA Subhumid Programme, adopting a farming systems research approach, identified poor nutrition in the dry season as the main constraint to cattle production in the subhumid zone of Nigeria. During this period, the natural pasture is not only scarce but also poor in quality, with a crude protein (CP) content of about 3%. This is below the critical 7% CP level required in the diet of ruminants. Cattle may lose up to 15-20% of their body weight during this season (Otchere, 1986). Also, milk yields are low, calf mortality is high and many cows are unable to conceive because of nutritional anoestrus.

A contributory factor to the low quality and productivity of the herbage in the subhumid zone is the poor nature of savanna soils. Intensive methods of agricultural production such as continuous cropping, land clearing and mechanised farming lead to nutrient losses through soil erosion, runoff and leaching. The organic matter of these soils is very low because the poor savanna vegetation contributes very little to the soil to replenish the fast decomposing organic matter. Burning and the removal of crop residues from the site for livestock feeding aggravate the situation.

Any attempt to promote livestock production in the subhumid zone should therefore consider a programme of soil fertility maintenance in addition to improving the nutritional value of the pasture. For instance, the poor carbon and nitrogen content of these soils could be improved by the incorporation of forage legumes into the cropping and fallow systems. The use of agro-industrial by-products such as cottonseed cake, groundnut meal, urea and molasses can improve the productivity of lactating and pregnant cows. However, supplies of these feeds are not readily available and prices are escalating. In view of these ecological and financial constraints, ILCA considered a sustainable enterprise such as planted forage legumes (fodder banks) to be a more appropriate long-term option.

Research is being conducted in three main case study areas. Kurmin Biri is a grazing reserve established by the government to assist pastoralist settlement. Abet is an intensively cultivated area where pastoralists settle amongst the arable farmers who are the landowners. Ganawuri is also intensively cultivated but by mixed farmers, who own both land and cattle.

THE FODDER BANK CONCEPT

A fodder bank is a concentrated unit of forage legumes established and managed by pastoralists near their homesteads for the dry season supplementation of selected animals. These legumes can fix soil nitrogen, and the protein content can stay above 8% for a greater part of the dry season. At present, *Stylosanthes guianensis* cv Cook and *S. hamata* cv Verano are the two main species recommended.

The guidelines for the establishment, management and utilisation of fodder banks are as follows:

(a) Depending on availability of land and number of animals, select an area (normally about 4 ha) close to the homestead.

(b) Prepare the seedbed by confining a herd overnight in the area for several weeks.

(c) Broadcast scarified seeds mixed with 150 kg/ha of single super phosphate fertilizer.

(d) Control fast-growing grasses by early season grazing.

(e) Allow the forage to bulk up by deferring grazing until the dry season.

(f) Ration the fodder bank by selecting the appropriate type and number of animals and limiting grazing to 2.5 hours per day.

(g) Ensure sufficient seed drop and adequate stubble for stylo regeneration in the following season.

Experiments have shown that supplementary feeding with 1 kg of cotton-seed cake (crude protein = 30%) daily, maintained the bodyweight of Bunaji cows throughout the dry season (Otchere 1986). It was predicted that cattle fed with 2.5 kg of dry stylo (crude protein = 12%) would derive similar benefits. With a potential stylo dry-matter yield of 4 to 5 tonnes per hectare, it was estimated that a 4-ha fodder bank should adequately meet the supplementary requirements of 15-20 pregnant and lactating cows for the six-month dry season if grazing is limited to 2.5 hours a day.

Benefits of the Fodder Bank

Animals with access to fodder banks in the dry season of 1983 produced more milk, lost less weight and their calves survived better (Bayer, 1986: Figures 1 and 2). This is supported by evidence from the comparison of herds with and without fodder banks (Table 1). The advantages of owning fodder banks is acknowledged by cattle owners as evidenced by an increase in the number of fodder banks in the subhumid zone from two in 1980 to 77 in 1986 (Figure 3), and financial support has been provided by the World Bank for the establishment of an additional 2000 fodder banks over the next five years.

Table 1. Effect of dam supplement.

Trait	No supplement	Supplement	Improvement
Cow survival (%)	92.2	96.0	4.1%
Calving percentage	53.8	58.1	8.0%
Calf survival (%)	71.8	86.3	20.2%
Calf weight at 1 year (kg)	98.1	103.4	5.4%
Lactation yield (kg)	300.2	312.5	4.1%

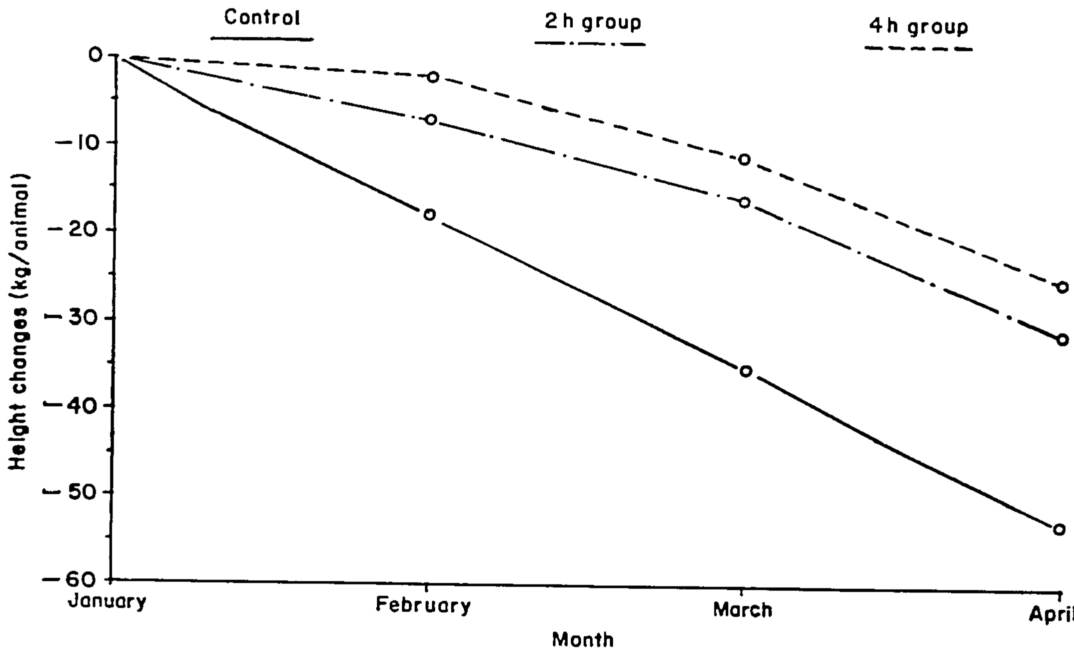
Source: Mani (1986).

Major Constraints to Fodder Bank Expansion

Social problems (land tenure system)

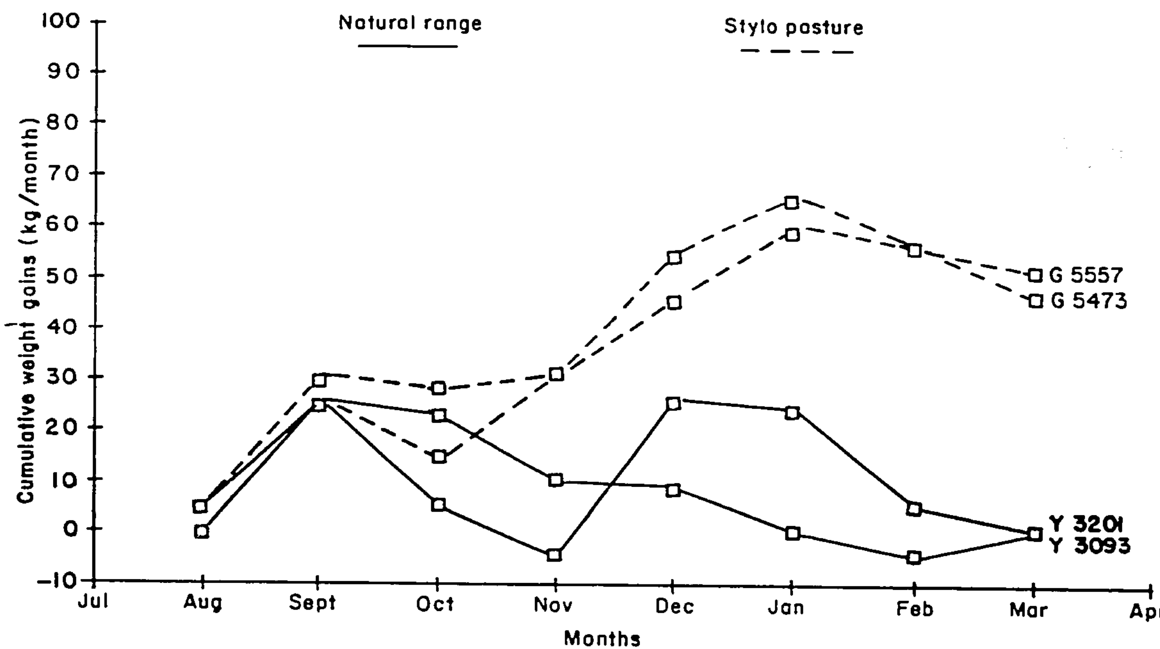
Among the three basic resources (land, labour and capital) required for the development of fodder banks, the difficulty of acquiring land by pastoralists has been identified as the most important limiting factor. The FulBe agropastoral cattle owners who were the original target group have no legal land rights in this part of the zone. Most indigenous farming communities generally have no direct interest in cattle production.

Figure 1. Weight changes of cattle in 1983/84 dry season grazing trial in Kurmin Biri.



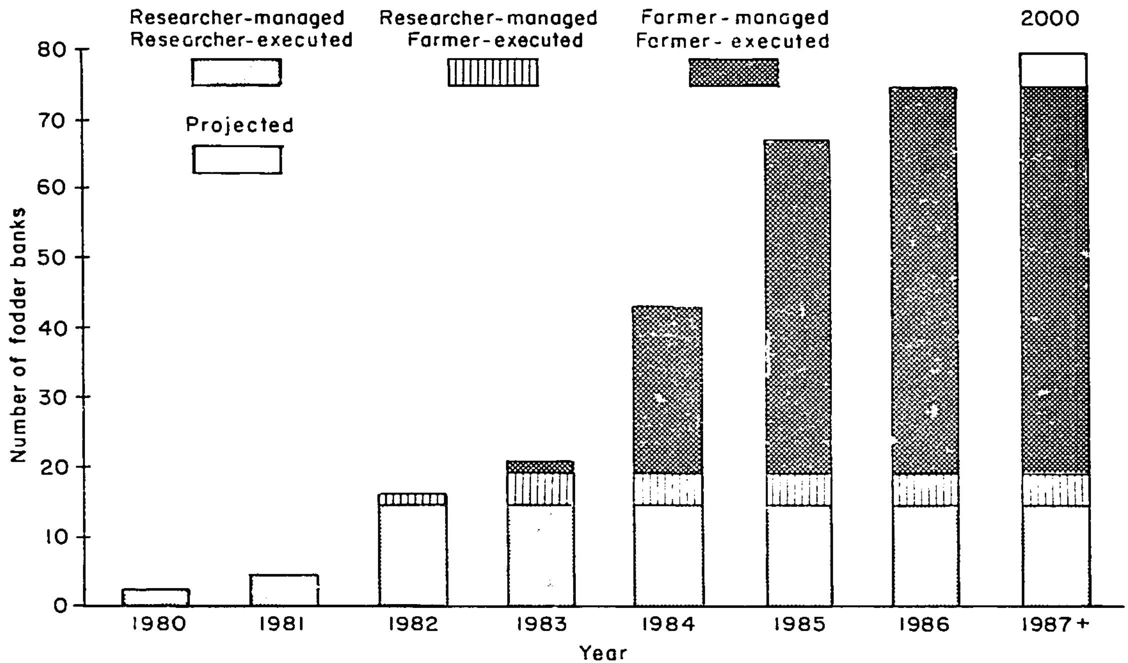
Source: Bayer (1986).

Figure 2. Cumulative weight gains of calves on stylo pasture and natural range for 10 months (Kurmin Biri 1984/85 grazing trial 1).



Source: Bayer (1986).

Figure 3. Number of fodder banks under different levels of management.



Source: Mohamed-Saleem (1986).

FulBe who are willing to settle on government grazing reserves find it easy to obtain land for fodder banks but there is only a limited number of grazing reserves. Most agropastoralists actually prefer to settle near crop farmers to have access to crop residues, better marketing facilities and social services. With an expanding population and consequent increasing demand for land for cropping, the pastoralists will face greater difficulties because the farmers retain the best crop land for themselves.

Moreover, they are typically reluctant to lease their unused land to cattle owners for pasture development because of their tedious procedures and safeguards that have to be negotiated under customary law. In certain areas, pastoralists are worried that farmers will go to the extent of hindering cattle owners from acquiring individual pasture plots even in grazing reserves. This clearly indicates that fodder bank technology will not be as widely adopted as desired in the subhumid zone unless it is of significant benefit to the farmers, as well as to the livestock.

Ecological problems (nitrophilous grasses)

Invasion of leguminous pastures by nitrophilous grasses (Gardner, 1984) reduces fodder bank productivity over time. This is because such pastures accumulate soil nitrogen through fixation of atmospheric N (Vallis and Gardner, 1984) which makes nitrophilous grasses very competitive. Since grasses grow faster than legumes, the latter are likely to be smothered, thereby lowering the nutritional value of the pasture especially if the grasses are not controlled. This was observed in a four-year-old *S. hamata* cv Verano fodder bank in the Kachia grazing reserve, which showed a rapid build-up of fast-growing grasses (Table 2). In a one-year-old fodder bank, stylo productivity, soil N and crude protein declined with an increase in grass density (Figure 4). In Thailand, mixed legume/*Setaria sphacelata* swards changed from legume dominance to grass dominance within two years (Andrews and Gibson, 1985). This implies that a system must be devised whereby the excess N can be periodically flushed out to check the invasion of nitrophilous grasses.

Cropping as a Solution

Cropping uses the accrued N, thereby restricting the growth of nitrophilous plants and favouring the legume component of the pasture. Nitrogen is the most limiting element for cereal crops and one of the most expensive fertilizers (FAO, 1984). Exploiting legume-fixed nitrogen through cropping will, therefore, interest the farmers and will encourage them to lend their land more readily to the FulBe for pasture development.

Previous work on legume-based cropping (Mohamed-Saleem, 1986) showed that maize-growing on fodder banks of various ages produced higher grain yields than on previously cropped and uncropped soils. Improvement in fertility and physical properties of the soil contributed to the increase in yield within the stylo area. Measurements on soils where the above experiments were carried out showed differences in bulk density, gravel, organic matter and nitrogen contents. ILCA's approach is to exploit this feature in order to encourage farmers to

Table 2. Frequency distribution (%) of major grasses in a four-year *S. hamata* cv Verano fodder bank at Kachia grazing reserve.

Species	Natural vegetation	Fodder bank
Andropogon spp.	6.2	13.3
Brachiaria ssp.	8.3	
Digitaria ssp.	0.8	
Hyparrhenia spp.	11.4	16.1
Loudetia spp.	40.7	4.0
Panicum spp.	0.8	
Paspalum spp.	1.4	0.4
Pennisetum spp.		0.5
Setaria spp.	0.6	0.8
Others	24.4	5.6
Legume		
S. hamata cv Verano		59.3

Source: Mohamed-Saleem *et al* (1986).

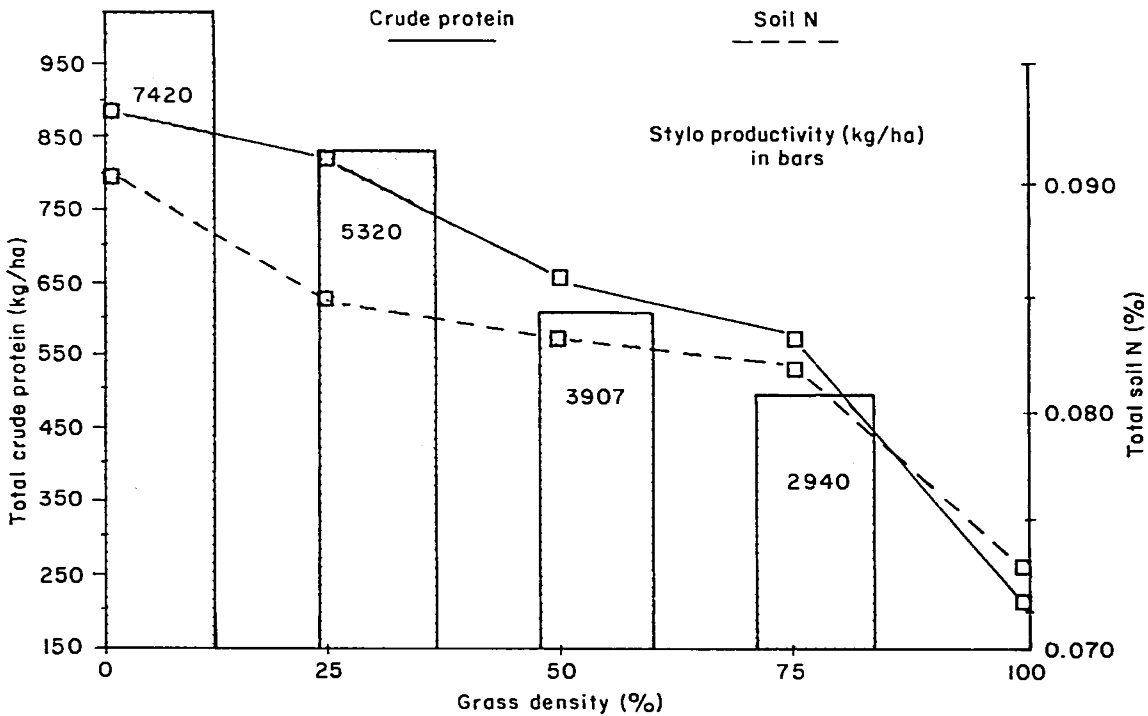
cooperate more readily with pastoralists seeking land for stylo establishment. Moreover, once the arable community recognises *Stylosanthes* as a soil conditioner, it will command the same care and respect as that given to crops. This will also indirectly alleviate problems such as the deliberate burning and indiscriminate grazing of fodder banks.

METHODOLOGY

A study was conducted during the 1985 growing season at Abet (9° 30'N, 8° 25'E, rainfall 1300 mm between April-October), one of ILCA's case study areas. Two fodder banks of *Stylosanthes hamata* cv Verano established three and four years previously and grazed during all consecutive dry seasons, were identified. Four plots each of 15 m x 10 m were laid out inside each fodder bank. The plots were set up in sites in which the legume component was representative of that found in fodder banks of the subhumid zone (50-60% stylo). Each plot formed a replication. Comparable plots which had remained as natural grass fallow for at least four years were also demarcated immediately outside the fodder banks.

The plots were ridged to a height of 30 cm in May at one-metre intervals and planted with three maize seeds (Variety TZPB) per hole at a spacing of 0.25 and thinned to one seedling after emergence. A uniform dose of N, P and K at the rates of 60, 60 and 60 kg/ha, respectively was applied as compound fertilizer (N P_{15} K_{15}) prior to planting and another 60 kg N/ha as urea was applied six weeks later. Plots were weeded five and eight weeks after sowing. At harvest, the cobs were first plucked then dehusked, dried and shelled to determine the grain yield. The stalks were cut and dried at 80°C to determine the dry weight of the crop residues. All data collected were analysed according to variance technique.

Figure 4. Effect of grass density on stylo productivity, total soil N and crude protein (Kachia 1985 wet season).



RESULTS

The grain yield and crop residues of the maize planted inside the fodder banks almost doubled that of maize sown outside the fodder banks (Tables 3 and 4).

Table 3. Grain yield (kg/ha) of maize growing inside and outside two fodder banks in Abet.

Location	Site 1	Site 2	Mean
Inside	4785	4533	4659
Outside	2411	2679	2545
LSD (0.01)	452	235	-

Table 4. Crop residue yield (kg/ha) of maize growing inside and outside two fodder banks in Abet.

Location	Site 1	Site 2	Mean
Inside	7212	7586	7399
Outside	4018	4523	4271
LSD (0.01)	2331	592	-

DISCUSSION

Even at the vegetative growth stages it could be seen that the maize planted in the legume-based soils was performing better than that grown on natural fallow. These visible differences led to the organisation of a field day for over 100 farmers and pastoralists in Abet on 12th August, 1985. They were quick to note the superior growth of maize inside the stylo area. The incremental income to farmers growing crops in fodder banks in Abet would be 124% of normal crop revenue resulting from a natural fallow (Kaufmann and Blench, 1986).

Despite years of contact with fodder banks, the demonstration trials enabled farmers for the first time to see in a direct, visual manner that legume-based pastures can be exploited for crops as well as livestock. As a result, farmers asked for *Stylosanthes* pastures to improve soil fertility in their fallows. Five of these have been established and more farmers are becoming interested in the package (Table 5). Initially, the small hectarage will be used for improving feed for small ruminants, but later it is hoped that the farmers will see the advantage of letting pastoralists seed and manage larger areas for them.

Table 5. Fodder banks for small ruminants in Abet.

Farmer agro-pastoralist	No. of ruminants	Size of fodder bank (ha)	Productivity (kg/ha)	% Stylo
Magaji Bala	8	0.1	3,604	58
Bayei Kaburuk	7	0.1	3,589	60
Tanko Agau	4	0.05	2,614	42
Achie Gariya	6	0.05	2,832	52
Bammi Buldi	30	1.0	4,836	62

There already exist farmer-pastoralist exchange relationships whereby pastoralists charge lower rates for manuring fields to farmers who ensure them first access to crop residues. At other times farmers arrange for herds of pastoralists to fertilize crop fields, so as to enjoy the benefit of cropping the area during the first year. In return, the pastoralists are allowed to cultivate the areas in subsequent seasons. This symbiosis could be developed further by incorporating forage legumes. The farmers could lend their fallow land to pastoralists for the establishment of fodder banks and thus improve their crop yields at the same time.

Future work will include the determination of the minimum area required to produce fodder that will support the average number of small ruminants kept by farmers. Management guidelines for the utilisation of the fenced pastures for both wet and dry season supplementation will be worked out. Also, the contribution of stylo to soil fertility and the performance of animals grazing on the fodder banks will be monitored.

Studies of the response of cereals to fixed nitrogen in fodder banks will be continued for newly opened and continuously cropped stylo soils in order to determine the most responsive crop and the fertilizer/labour requirements for cropping such soils. A crop-legume rotational system will be introduced in the larger (4 ha) fodder banks.

CONCLUSION

Stylosanthes-based cropping serves the dual purpose of maintaining forage quality and improving crop yields. Thus, it can benefit both farmers and agropastoralists. Cropping stylo areas, hitherto considered as optional in fodder bank management, should now be regarded as an essential practice.

Farmers and agropastoralists in Kurmin Biri, Abet and Ganawuri (ILCA case study areas) have seen this potential for cropping stylo areas. Since tilling these soils does not require more labour than a natural fallow (Tarawali *et al.*, 1986) they have started to crop part of their fodder banks and legume fallows. While *Stylosanthes* pastures were originally meant to promote livestock production, their continued spread across the subhumid zone will be a boost to crop production as well.

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ROLE OF CROP RESIDUES AS LIVESTOCK FEED IN ETHIOPIAN HIGHLANDS

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Abstract

Ethiopia is known for large livestock populations of which 80% are raised in the highlands where intensive crop farming is also undertaken using ox traction. Crop residues particularly cereal straws are the major livestock feed particularly in the dry seasons, providing 40-50% of the total annual livestock feed.

Evaluation of nutritional value of crop residues shows that they are generally low in digestibility and protein content.

Improving intake and digestibility of crop residues by physical and chemical treatments (NaOH NH_3) are technically possible but they do not have practical value in Ethiopia at present. Supplementation of crop residues with molasses, oilseed meals and leguminous fodder crops have been observed to increase both intake and digestibility of crop residues, and the system is being developed.

Intercropping cereals with leguminous fodder crops and supplementation of crop residues with foliages of Leucaena, Sesbania, *etc. and hays of* Trifolium, *alfalfa and vetch appear to have much practical value in mixed farming systems of the Ethiopian highlands.*

INTRODUCTION

Ethiopia has the largest livestock population in Africa with approximately 26 million head of cattle including about six million draught oxen. About 80% of these animals are raised in the intensively cultivated highland part of the country. The Ethiopian highlands cover 490,000 km^2 or about 40% of the country and almost half of the total African highland area (Gryseels and Anderson, 1983).

Ethiopia has unique agricultural features such as the use of teff (*Eragrostis tef*) as a cereal and enset (*Musa ensete*) as a root crop, an indigenous system of ox traction and the extensive use of equines (seven million) for transport (Jahnke, 1982).

Land use is dominated by mixed smallholder rainfed agriculture producing cereals, pulses and livestock. Crop production and livestock husbandry are commonly integrated in the mixed farming system of the medium-highland zones of Ethiopia. Oxen are important suppliers of draught power for land development, tillage, threshing and transport which means that the more crop production is increased, more and more oxen are required. This fact is even more realistic in most parts of high potential agricultural zones of Ethiopian highlands due to the uneven nature of the landscape. In Ethiopia, about six million ha of land are put under annual grain crops; mainly wheat, barley, teff, maize, sorghum and pulses.

As more and more land is put under crop production, livestock feed becomes scarce and crop residues particularly cereal straws remain the major feed source for the animals particularly during the dry period of the year (which spans the November to May period). Some estimates indicate that crop residues provide 40-50% of the annual livestock feed requirement.

This paper contains current practices of straw utilisation and reviews efforts made to improve nutritional quality of crop residues in Ethiopia.

CURRENT PRACTICES

Straw Utilisation

From about 6 million ha of farmland about 12 million tonnes of crop residues (grain yield 10 qt/ha and 2:1 straw to grain ratio) are annually produced in Ethiopia of which about one-third is left in the field for aftermath grazing (stubbles).

Farmers use crop residues for different purposes, e.g. for fuel as firewood and minor constructions, especially maize and sorghum stovers; for roofing local houses, in the case of wheat, oat and barley straws; as binding material for walls of local houses, especially teff straw. But the major use is for livestock feed particularly for draught oxen during dry seasons.

Animals feed on crop residues mainly in two ways. The residues are piled in stacks near homesteads and animals are let to eat from the stacks or given small quantities in the morning and evening, or for working oxen, before and after work. Alternatively, the residues are left in the threshing ground and consumed by animals together with the standing straws which are left for aftermath grazing.

In some parts of the Ethiopian central highlands farms and government-owned fattening feed lots use straws with molasses and urea. There is a strong tendency towards improving the utilisation of crop residues by supplementing with molasses and/or urea at beef farms. And at some farmer cooperatives pen fattening of cull cows and old oxen is practiced on straw-based diets.

Production of Crop Residues From Different Crops

Grain and straw yields of different crops are shown on Table 1. Yields of grain and crop residues are highly correlated. High grain yields are the result of high vegetative growth which is associated with high production of crop residues. The straw to grain ratio for wheat varieties ranges from 1.8 to 2.9 and of barley from 1.9 to 2.6. It appears that varieties of low yield potential produce the highest straw to grain ratio i.e. have the lowest harvest index.

Table 1. Mean yields of grain, residues, harvest indices, CP and CF (% of DM) of different crops in Arsi Region, Ethiopia.

Crop varieties		Grain yield kg/ha	Residue kg/ha	Total kg/ha	Residue to grain ratio	Harvest index %[c]	% CP	of DM CF
Wheat	Enkoy	4585	9808	14393	2.1	32	4.99	38.0
	Romany	4000	10872	14872	2.7	27	5.04	40.0
	K6295-4A	2890	7969	10859	2.7	27	4.85	35.5
	Bulk	3822	9400	13222	2.5	29	5.28	36.5
	Dashen	5156	9138	14294	1.8	36	4.36	37.5
	Gara	4448	9813	14261	2.2	31	5.28	35.0
	Batu	3953	8590	12543	2.2	32	5.72	31.3
	Local	2392	6862	9254	2.9	26	4.70	40.0
Barley	Improved (food)[a]	2737	7004	9741	2.6	28	4.4	36.6
	Improved (malt)[b]	2918	5972	8890	2.0	33	5.7	36.2
	Arusso	3180	5900	9080	1.9	35	4.30	39.0
	Local	1982	4665	6647	2.4	30	5.76	35.0
Tef	DZ-354	2100	7100	9200	3.4	23	3.83	29.0
Horsebeans		2200	3900	6100	1.8	36	7.67	48.0
Fieldpeas		2340	12000	14340	5.1	16	13.8	41.0

a IAR 485, A-HOR.
b HB37, HB42, Holker.
c $\text{Harvest index} = \frac{\text{Grain yield (kg)}}{\text{Total above-ground weight (kg)}}$

Samples were collected from trial plots and the Seed Multiplication Farm, so that the yield figures for different crops might deviate from what is normally expected. However, the figures shown for residue to grain ratio harvest index and contents of crude protein and crude fibre can safely be used for rough estimation.

Reed *et al.* (1986) have also demonstrated that high grain yielding varieties of sorghum (in Ethiopia) can also yield reasonably high amounts of crop residue with high nutritive value.

Nutritional Quality

As shown in Table 1 there are considerable variations in the contents of crude protein and crude fibre among different crop residues and varieties of the same crop.

Nutritional values of different crop residues and some forages are shown in Table 2. Chemical composition of the cereal crop residues contain a large proportion of lignocellulosic cell wall constituents and have low crude protein contents. Thus one could expect both voluntary intake and digestibility of the crop residues to be low. Generally, cereal crop residues have an energy content of less than 7.0 MJ/kg dm. As shown in Table 2 the digestible protein content of cereals is below 20 mg/kg which is only about 25% of that from grazing grasses. Legume straws contained less crude fibre, higher digestible protein and calcium than cereal straws.

Quite a remarkable difference between the crude protein contents of cereal and legume straws was observed. Comparing Tables 2 and 3 it can be estimated that the digestible protein contents of wheat and barley straws is about 40 and that of pulses is about 45% of the total crude protein contents which implies that figures of crude protein contents are not the best measurement of quality but that digestibility is more important.

Table 2. Nutritional values of some straws and fodder crops.

	Fibre % of DM	Digestible protein g/kg	Ca g/kg DM	P g/kg DM	Energy MJ/kg DM
Barley straw	39.5	18	3.0	0.8	6.8
Wheat straw	41.0	14	2.4	0.7	6.2
Tef straw	35.9	19	4.1	0.5	6.8
Pea straw	26.0	40	13.2	0.6	7.1
Bean straw	40.1	20	5.2	0.5	6.8
Native grasses[1]	28.9	87	3.9	1.6	8.9
Improved grasses					
(tropical)[1]	28.2	79	4.3	1.4	8.7
(temperate)[1]	25.4	119	4.8	1.9	9.1
Vicia[1]	33.2	146	12.0	1.4	9.1
Alfalfa[1]	22.2	186	28.0	2.4	10.4

[1] Included for comparison.
Source: Evaldson (1970).

Table 3. Chemical analyses of different straws at Chilalo, Ethiopia.

Crops/varieties	% Dry matter	% Crude protein	% Crude fibre	% Ash
Barley improved (varieties)	92.7	4.6	41.4	10.6
Barley local (varieties)	93.5	5.4	43.5	11.8
Wheat improved (varieties)	92.5	3.7	43.0	9.9
Wheat local (varieties)	93.0	4.0	45.4	10.8
Triticale	91.0	2.4	41.5	10.4
Tef	91.3	4.2	38.8	6.7
Maize (cobs, stalks)	92	3.5	33.6	4.6
Sorghum	91.5	1.7	40.0	4.9
Horsebeans	92.2	4.0	43.4	10.3
Fieldpea	93.5	9.7	47.3	9.6
Lentiles	91.5	5.1	52.5	4.4
Flax	90.5	4.9	49.5	4.2
Chickpea	93.0	9.2	49.8	4.3
Vicia dasycarpa	93.5	9.8	41.2	11.2

Improvement in Nutritional Quality of Crop Residues

Straws are poor quality feed because they have a low ME content (often less than 7.5 MJ/kg/ DM). Variations are caused by varietal differences, season of planting, harvesting conditions and height of cut.

The feeding value of straw depends on intake and digestibility. To achieve maximum intake of straw a crude protein content of 66-85 g/kg DM is necessary. Maximum intake of DM has been observed when crop residues form 16-35% of the diet.

From studies at ILCA in Ethiopia (Mosi and Butterworth, 1985) showed that cereal crop residues are often less than 50% digestible and intake is usually 50 g/kg LW 0.75 or less.

Preston and Leng (1987) reported that straws from various species of grain crops appear to be highly variable in *in vitro* digestibility and the crude protein content is always low (Table 4).

Table 4. *In vitro* **OM digestibility and N content of straws from different crops.**

	In vitro OM dig. %	N content % DM
Wheat straw	28-58	0.4-1.0
Oat straw	34-68	0.4-1.0
ice straw	40-52	0.5-1.0
Barley straw	34-61	0.4-1.0
Maize	31-50	0.5-1.2
Sorghum leaves	65-78	0.5-0.8

Generally, crop residues are poor quality feed so that their digestibility is low, and also they contain low N which limits voluntary intake and nutritional value.

Straw Treatments

Physical treatments

The most commonly used physical treatment has been grinding. It reduces particle size and increases the surface area of the straws exposed to rumen microbial action. Straws have the disadvantage of being extremely bulky, making costs of transportation high per unit of nutritive value. One advantage of grinding or fine chopping is to reduce the bulk of the materials.

Soaking straw in water just before feeding has also been practised to increase dry-matter intake and hence digestible organic-matter consumption (Chaturvedi *et al.*, 1973; Holzer *et al.*, 1975).

Sundstol (1981) and Nicholson (1981) have reported that high pressure steam, high temperature treatment and irradiation of straws - are effective in increasing the digestibility under laboratory conditions. This practice appears to be costly and might not be used in the foreseeable future at small-scale livestock husbandry systems such as those in Ethiopia.

Chemical treatments

The most widely used chemicals to treat straws have been sodium hydroxide (NaOH) and ammonia (NH_3). It has long been known that soaking in lime (alkaline solution) improves intake and digestibility of straw. Butterworth and Mosi (1986) (quoting Jaasuriya) reported that treating roughages with sodium hydroxide can increase their digestibility by 10-20 percentage points and increase intake by 30-50%. Studies conducted in U.K. (FAO, 1977) show that inclusion of up to 30% treated straw (with 5-6% NaOH) in complete diets has not depressed production of milk or beef.

Ammoniation of crop residues using gaseous ammonia or through wet ensiling (for 10-30 days) with urea (4-5%) has been found applicable for practical use at present.

Preston and Leng (1987) reported that this practice increases digestibility by 5-10% units, nitrogen content of the straw, and acceptability and voluntary intake of the treated straw by 25-50% as compared to untreated straw.

In Ethiopia, urea (46% N) is dissolved in water and sprinkled over the residues and fed at the rate of 75-100 gm/day/animal in some beef production feedlots.

Supplementation

With molasses

In Ethiopia, over 50,000 tonnes of molasses is produced annually of which about 55% is exported (Alemayehu Mengistu, 1985). The practice of using molasses as a supplementary feed for livestock has not been well understood at present. Due to the drought problem in 1984/85, the Ministry of Agriculture and ILCA jointly conducted some studies and as a result of this work molasses/urea mixtures are being used as a strategic feed reserve in the drought stricken areas and as a routine feed in cattle fattening farms. Molasses is used as a palatable carrier for urea and minerals for improving the utilisation of crop residues. Molasses/urea mixtures are used also as the basis of a supplement to crop residues for routine feeding during the dry season. In cattle fattening enterprises, Preston (1985) recommended that molasses (at free choice) should be supplemented with 2.5% urea, cereal straw (0.8% liveweight on dry-matter basis) and protein meal about 0.25% of liveweight basis.

With oil cakes

Most of the oil seed plants such as noug (*Guizotia abyssinica*), linseed, groundnuts, rapeseed, sesame and sunflower are widely grown in Ethiopia. The cakes of these crops are widely used as a protein supplement to low quality hays and crop residues.

With leguminous fodders

Leguminous forage crops which are rich in protein and usually high in digestibility have been found beneficial as a supplement to improve intake and digestibility of crop residues. From studies conducted in Ethiopia, Mosi and Butterworth (1985) found that addition of 20-25% *Trifolium tembense* hay to teff straw increased feed intake of sheep by 20-30%. In another study Butterworth and Mosi (1986) reported that where hay from *Trifolium* is supplemented to residues of teff, oat, wheat and maize at the rate of 30% by weight, dry-matter digestibility was increased by about 10 percent units as compared to straws alone (Figure 1).

Olayiwole *et al.* (1986) have also obtained satisfactory growth rates of crossbred dairy heifers by feeding cereal crop residues supplemented with small amounts of maize and urea and additional protein from *Trifolium* hay and noug meal (Table 5).

Improving cereal crop residues by supplementing with green forage legumes such as foliage from *Leucaena*, *Sesbania*, pigeon pea or hays from *Trifolium*, alfalfa and vetch, is the most practical method which can be adopted locally by small-scale farmers. Growing forage legumes on land that could otherwise be fallowed has the additional benefit of increasing the yield of subsequent crops through the nitrogen fixed by the legume.

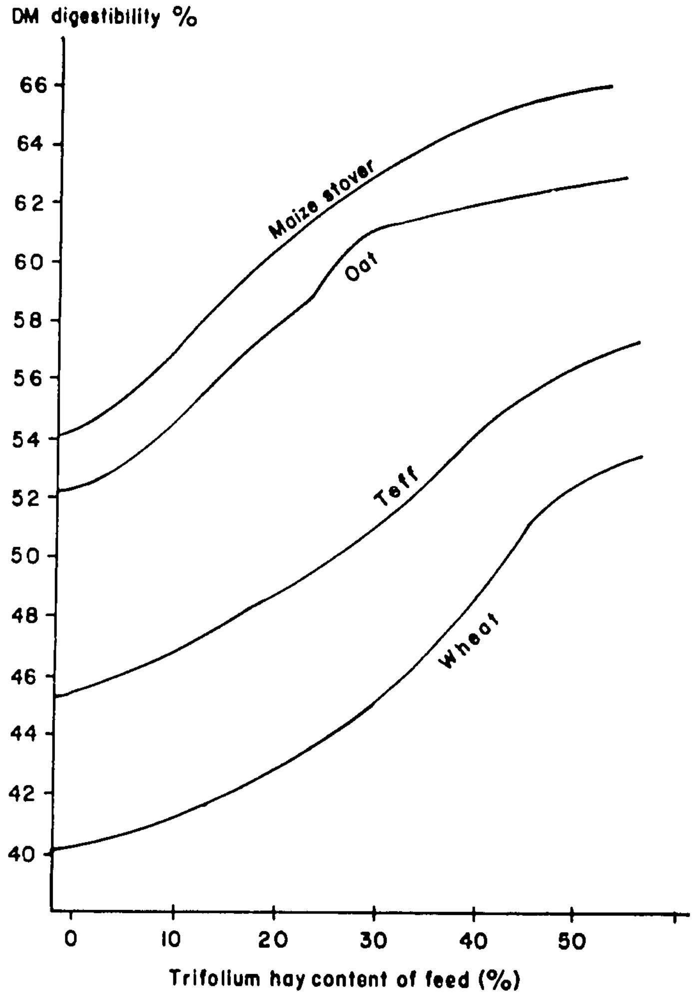
Table 5. Pooled mean values of total dry-matter intake (g/kg $LW^{0.75}$) and weight gain (g/day) by animals fed different combinations of cereal crop residues (teff and wheat), *Trifolium* hay, urea and noug meal.

	-Trif	+Trif	No urea or no noug	Urea	Noug
DM intake (gm/kg $LW^{.75}$)	76.5	80.7	72.2	71.7	86.8
Wt gain g/day	133	227	72	179	289

Source: Olayiwole et al. (1986).

Intercropping cereals with legumes such as *Dolichos* with maize or sorghum (Haque, ILCA, Addis Ababa, Ethiopia, unpublished data) can improve the nutritional value of the residues. This practice appears more appropriate and a cost-effective way as compared to other methods of improving the nutritional value of crop residues.

Figure 1. Effect of addition of *Trifolium* hay on dry-matter digestibility of cereal straws.



Source: Butterworth and Mosi (1986).

CONCLUSION

In high potential agricultural zones of the Ethiopian highlands more and more land is being cultivated for crop production every year to satisfy the increasing human demand for food. Consequently, the grazing lands are becoming scarce and crop residues remain the main feed source for livestock. The limiting factors with the utilisation of crop residues as livestock feed are low voluntary intake and poor digestibility. Emphasis is being given to assess implications of a more widespread use of crop residues as livestock feed and possibilities of improving nutritional value.

Various methods of physical and chemical treatments of straws have been developed. Both treatment methods have been found to require heavy investment on machinery followed by regular availability or supply of replacement parts and chemicals which would not be feasible for small-farmer level at present in Ethiopia. Growing fodder legumes and use of these fodders as supplement to crop residue is the most practical and cost-effective method of improving nutritional value of crop residues. This creates an opportunity for crop residues to play a useful role in reducing weight losses of animals particularly during dry periods.

Better use of crop residues ought to be stressed, and research efforts must be directed to develop methodologies by which the utilisation of this resource could be increased. Plant breeders seldom consider the fact that crop residues are the most, often the only, available livestock feed resource when selecting crop varieties for high grain yields. Straw yield and nutritional quality might have to be considered when new varieties are developed.

Possibilities of sowing legumes under cereals and improvement of the nutritional qualities of crop residues by supplementations with leguminous fodders should be emphasised in the future.

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NUTRIENT QUALITY OF FORAGES IN ETHIOPIA WITH PARTICULAR REFERENCE TO MINERAL ELEMENTS

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Abstract

Hays, range grasses, crop residues and browse trees from different parts of Ethiopia were analysed for nitrogen, fibre components and mineral concentrations. Pasture grasses and crop residues studied had very low crude protein contents, while the browse on the average had more than 15% crude protein. Almost all the forages had sufficient levels of K, Ca, Mg, Mn and Zn to meet requirements of ruminant animals, but the occurrence of marginal to deficient supplies of Na, Cu and P appear very likely. There is an urgent requirement for experimentation on supplementation regimes involving these minerals, so that appropriate recommendations can be formulated.

INTRODUCTION

In Ethiopia, as elsewhere in Africa, malnutrition impairs livestock production. Ethiopia's overall livestock productivity is below average. Although 12.7% of Africa's 524.61 million cattle, sheep and goats are found in Ethiopia, the country produces only 7.3% and 5.1% of Africa's total meat and milk production respectively (FAO, 1985). Grazing animals in Ethiopia subsist mainly on poor quality feedstuffs in the form of poor quality pastures in arid and semi-arid areas and hays and/or crop residues in the arable areas. In a few of the animal production centres where improved management is undertaken, the main supplements are energy and protein in the form of agro-industrial by-products such as cereal brans, molasses and oilseed cakes. Scant attention is given to the mineral content and nutritional balance of such diets. It has been widely established that available energy and protein of a feed are of primary importance to any animal but optimal performance is only possible if there is an adequate supply of minerals and vitamins (McDowell, 1985).

In Ethiopia, cattle rarely receive mineral supplements except occasionally common salt. Pastures are thus the main source of minerals, and only rarely can forages completely satisfy all mineral requirements of livestock (Miles and McDowell, 1983). Mineral status of grazing animals in Ethiopia and other African countries has received very little attention. This may be due partly to the fact that the methodology of mineral nutrition studies, especially of trace elements, is rather complicated and signs of marginal mineral deficiencies are not easily detected but frequently it is mistakenly assumed that the grazing animal will obtain its mineral needs from the pasture. Mineral deficiencies, even if marginal, can result in depression of animal performance. Subclinical mineral deficiencies are often widespread and are responsible for as yet unestimated, but probably great, economic losses in livestock production.

An earlier mineral study in Ethiopia (Faye *et al.*, 1983) indicated probable widespread copper and zinc deficiencies, and although much more information on the supplies of essential minerals for livestock is required, it is very likely that mineral deficiencies contribute to the poor performance of livestock in Ethiopia. Before measures can be undertaken to correct these deficiencies, it is necessary to assess the mineral status of forages and of the grazing animals as well as their production responses to mineral supplementation. This study was undertaken to investigate the nutrient status, with special regard to minerals, of the common crop residues, pasture grasses, grass hays and browse trees used as livestock feeds in Ethiopia.

METHODOLOGY

Samples

Samples of meadow hay were collected from an ILCA site in Addis Ababa and from two other sites at Debre Berhan (an ILCAstation 120 km east of Addis Ababa and a Government sheep breeding station 132 km from Addis Ababa). Samples were also taken from a commercial source in Addis Ababa, whose supplies came from the Addis Ababa region. All the samples were from the highlands (2500-3000 m) and were obtained by pooling core samples from ten positions within the stack. Samples of oats hay (whole plant with grain), ryegrass hay and improved pasture hay (mostly ryegrass and native *Trifolium* species) were taken as described above from stacks of hay at ILCA sites in Debre Berhan harvested between September and November, 1986.

Sesbania sesban grown at ILCA, Addis Ababa and in Yabello in the southern Ethiopian rangelands of Sidamo were harvested in February, 1987. Samples were taken by pooling leaves from mature trees (50 in Addis Ababa and 15 in Sidamo). Leaves from the trees in Addis Ababa were further separated into young (first ten leaves on twig) and old. Pods with seeds on trees from Addis Ababa were first air-dried and then separated into pods and seeds. Samples of *Leucaena leucocephala* cv Peru were taken in February, 1987 from a lowland area at a Government research station (Institute of Agricultural Research, Melka Worer) in eastern Ethiopia using the same procedures as for *Sesbania*.

Grass and browse species were collected from the Sidamo southern rangelands in February, 1987 by hand plucking during grazing observations over three days. The species collected included: *Cenchrus ciliaris, Themeda triandra, Chrysopogon aucheri, Pennisetum mezianum, Acacia brevispica* and *Acacia nilotica*. The *Acacia* samples were of the species mainly browsed by camels and goats.

Samples of crop residues were taken using the same procedures as for hays. The crop residues were of highland origin, and most of them were being used in feeding experiments at ILCA, Debre Zeit and ILCA, Addis Ababa.

Chemical Analysis

Dry matter was determined after drying in a microwave oven at 60°C for 24 hours. The dried samples were ground using a one-mm sieve and stored in plastic bottles ready for analysis. Neutral-detergent fibre (NDF), acid-detergent fibre (ADF), lignin and ADF ash were determined with a microfibre apparatus using the procedures of Goering and van Soest (1970).

Samples were prepared for mineral analysis by the wet digestion method using concentrated sulphuric acid in presence of hydrogen peroxide. Nitrogen (N) and phosphorus (P) concentrations in the extracts were determined with the autoanalyser which uses ascorbic acid as a reducing agent for P determination. The concentrations of potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) were determined by atomic absorption spectroscopy. Sulphur (S) in the samples was quantified using the turbidimetric method of Cottenie *et al.* (1982).

RESULTS AND DISCUSSION

The analytical results for hay and range grasses are shown in Tables 1 and 2, for crop residues in Tables 3 and 4 and for leguminous trees in Tables 5 and 6.

Table 1. Dry matter, crude protein, NDF, lignin, ash and ADF ash of some hays from Ethiopian highlands and range grasses from southern Ethiopian rangelands.

Sample description	DM	CP	NDF	ADF	Lignin	Ash	ADF ash
	%						
Highland hays							
Meadow hay, DBSBS	93.4	5.3	69.7	37.9	4.0	7.5	2.4
Meadow hay, ILCA-DB	93.1	4.4	69.2	37.9	4.9	7.9	2.8
Oats hay, ILCA-DB	91.2	5.1	71.0	38.1	4.5	4.6	1.5
Rye grass hay, ILCA-DB	92.5	6.2	57.5	35.7	5.0	7.4	2.6
Improved pasture hay, ILCA-DB	92.0	5.3	58.7	32.7	4.0	6.5	3.1
Meadow hay, ILCA-Addis	94.1	4.6	72.2	43.7	5.7	8.7	3.4
Meadow hay from commercial centre	91.9	3.7	77.0	41.1	5.1	8.4	3.4
Range grasses							
Cenchrus ciliaris	58.8	7.5	66.2	37.2	5.1	11.3	4.06
Themeda triandra	84.7	5.0	77.2	50.2	8.0	10.9	7.61
Chrysopogon aucheri	59.1	6.0	71.2	36.0	5.2	11.5	5.80
Pennisetum mezianum	78.0	6.3	74.1	46.0	8.5	10.7	4.60

Table 2. Mineral content of some hays from Ethiopian highlands and range grasses from Ethiopian Sidamo southern rangelands.

Sample description	K	Na	Ca	Mg	P	S	Fe	Mn	Zn	Cu
	g/kg						mg/kg			
Highland hays										
Meadow hay, DBSBS	17.6	0.4	3.4	1.6	1.6	3.0	695	207	45	5.9
Meadow hay, ILCA-DB	18.4	0.3	4.4	1.6	1.4	2.6	974	274	39	6.1
Oats hay, ILCA-DB	12.6	0.9	1.6	1.0	1.8	1.8	192	96	30	7.0
Ryegrass hay, ILCA-DB	16.3	1.1	3.8	1.7	2.2	2.1	397	214	32	7.9
Improved pasture hay, ILCA-DB	20.8	1.2	3.7	1.7	1.6	2.6	358	206	28	7.1
Meadow hay, ILCA-Addis	17.5	0.6	4.9	1.7	1.4	2.4	191	246	29	6.2
Meadow hay, from commercial centre	13.1	0.5	4.6	2.1	1.6	3.0	589	322	37	7.9
Range grasses										
Cenchrus ciliaris	*23.5*	*1.0*	*2.0*	*1.6*	*1.5*	*2.1*	*830*	*45*	*24*	*3.6*
Themeda triandra	12.0	0.1	4.1	1.5	1.2	1.0	625	72	31	3.5
Chrysopogon aucheri	1.0	0.08	2.2	1.6	1.0	1.1	882	63	32	5.6
Pennisetum mezianum	12.0	0.1	3.2	2.0	1.4	1.1	452	72	40	4.7

Table 3. Dry matter, crude protein, NDF, ADF, lignin, ash and ADF ash of some crop residues from Ethiopian highlands.

	DM	CP	NDF	ADF (%)	Lignin	Ash	ADF ash
Wheat straw	90.5	1.6	70.7	50.6	11.1	10.8	5.5
Barley straw	88.2	1.8	65.4	56.2	7.0	7.7	1.7
Teff straw	89.7	1.7	71.3	49.1	7.9	7.8	3.7
Oats straw	88.9	1.5	57.2	41.9	6.0	8.3	2.1
Linseed straw	93.0	3.0	68.7	-	-	8.4	3.1
Maize stover	87.2	1.5	68.1	47.1	7.9	9.2	3.1

Table 4. Mineral concentration of some crop residues from the Ethiopian highlands.

	K	Na	Ca	Mg	P	S	Fe	Mn	Zn	Cu
	g/kg						mg/kg			
Wheat straw	14.8	0.3	4.1	1.5	1.3	1.4	325	78	11	3.0
Barley straw	10.7	0.5	4.6	1.4	1.9	1.2	1175	90	12	5.0
Teff straw	11.7	0.3	4.3	1.9	1.6	1.6	170	59	26	6.5
Oats straw	17.7	0.4	3.9	1.8	1.7	1.7	196	191	17	14.0
Linseed straw	10.7	0.6	7.7	2.2	1.3	1.6	103	71	24	14.0
Maize stover	17.8	0.5	3.3	2.5	1.7	0.9	408	61	24	5.9

Table 5. **Dry matter, crude protein, NDF, ADF, lignin, ash and ADF ash of** ***Leucaena leucocephala, Sesbania sesban*** **and** ***Acacia*** **species.**

Sample description	DM	CP	NDF	ADF	Lignin	Ash	ADF ash
	%						
Leucaena:							
Young leaves	20.7	31.2	25.1	10.6	0.3	6.5	-
Old leaves	34.1	28.6	23.4	13.4	2.4	8.9	-
Pods	79.1	7.9	67.8	61.1	19.6	5.7	-
Seeds	97.3	34.8	33.9	21.2	2.1	4.2	
Sesbania:							
Small twigs with leaves	29.0	27.5	14.0	12.4	2.8	12.4	0.3
First ten leaves	31.3	28.5	13.3	9.2	2.4	6.3	0.2
Old leaves	30.4	28.5	12.7	9.8	2.6	7.8	0.4
Pods with seeds	27.5	21.0	50.4	40.4	6.6	2.7	0.5
Pods alone	90.8*	10.6	60.9	52.6	13.9	6.4	0.3
Seeds alone	89.8**	34.6	33.0	22.4	2.6	3.7	0.3
Old and young leaves*	33.6	25.9	13.0	9.9	1.7	13.6	0.8
Acacia:							
Acacia brevispica	38.9	26.3	47.3	29.0	13.0	8.4	0.60
Acacia nilotica	40.1	15.0	30.7	28.1	11.0	5.9	0.60

* Taken from the low-mid altitude southern Ethiopia rangelands.
** First air-dried.

Table 6. **Mineral content of** ***Leucaena leucocephala, Sesbania sesban,*** **and** ***Acacia*** **species.**

Sample description	K	Na	Ca	Mg	P	S	Fe	Mn	Zn	Cu
	g/kg						mg/kg			
Leucaena:										
Young leaves	20.4	0.3	3.7	1.9	3.1	3.4	181	31	39	10.0
Old leaves	16.7	0.3	18.4	3.9	2.1	2.5	214	53	19	11.8
Pods	13.6	0.4	15.4	0.6	0.4	-	198	43	11	3.4
Seeds	15.6	0.3	3.4	1.9	3.8	4.9	131	29	40	11.0
Sesbania:										
Small twigs with leaves	13.0	1.2	21.3	2.8	2.1	2.3	274	165	41	9.5
First ten leaves	10.9	1.2	23.4	2.7	2.1	2.3	285	200	48	8.1
Pods with seeds	19.9	1.0	6.3	1.2	2.6	1.7	109	45	37	5.2
Pods alone	12.8	1.1	12.0	0.9	1.1	1.2	581	63	31	5.3
Seeds alone	9.3	0.8	3.7	1.4	4.6	1.9	181	52	52	7.6
Old and young leaves	13.2	1.0	28.3	4.9	2.4	3.2	280	410	62	6.4
Acacia brevispica	16.9	1.04	7.7	2.9	2.0	3.4	151	137	46	6.9
Acacia nilotica	8.1	0.5	18.0	1.9	2.2	2.3	664	66	31	9.0

* Taken from the low-mid altitude southern Ethiopian rangelands.

All the pasture grasses and crop residues studied had very low crude protein contents which is characteristic of mature tropical forages whose protein content declines rapidly following the rapid growth of the rainy season. Those figures were all below the level of 7.5% considered to be required for optimum rumen function (van Soest, 1982).

For reasonable levels of production, animals subsisting on these forages will therefore require supplementary protein which may be in the form of oilseed cakes and/or NPN sources such as urea which could be easily obtained locally. While use of such sources is practicable on smallholder units, it is not easy to do so for cattle on range in pastoral areas. In such situations it is possible to achieve some success through the use of high protein browse and tree crops such as *Sesbania*, *Leucaena*, *Gliricidia* and *Acacia* species (Table 5). On smallholdings in the highlands, where feeding hay is practised, effort could be made to improve the quality of the hay by practising early cutting, although the problem here is to compromise quantity with quality. Since hay is now being marketed in Ethiopia, a degree of quality control could be achieved if analyses were carried out and a system of price premium for good quality was introduced. The high levels of ADF ash in most of the grasses indicates the presence of large amounts of silica which may seriously reduce digestibility (van Soest, 1982).

In relation to the essential mineral elements, the level of K in all the forages was above the level of 8 g/kg recommended for grazing animals (Underwood, 1981). It has, however, been suggested (McDowell, 1985) that weaned calves and high producing dairy cows under stress, such as heat stress, may require K level above 10 g/kg, but since only the straws of barley, teff and linseed approached this figure, it seems most unlikely that problems of K deficiency are likely to arise. The same conclusion appears valid for S, Fe and Mn, the contents of which in almost all the forages studied were above the levels of 1 g/kg, 50 mg/kg and 40 mg/kg respectively proposed as adequate for grazing animals (McDowell, 1985). The requirement for S is basically related to that for N and S-containing amino acids, such that the ARC (1980) suggested that an N:S ratio of 14:1 is indicative of adequacy of S; in this regard, all of the materials examined are satisfactory.

With reference to Na, there is some debate in the literature concerning the dietary concentration required. While Underwood (1981) recommended 1 g/kg for most grazing animals, the findings of Morris (1980) and Little (1987) indicate that 0.7 g/kg is adequate for non-lactating cattle, and the ARC (1980) suggested that a level of 1.4 g/kg is required by sheep. The present data show that with the exception of *Sesbania*, most of the materials examined were very poor sources of Na, such that routine supplementation is likely to be necessary. This characteristic of *Sesbania* has been recorded elsewhere in the tropics (Little, 1986).

While dietary Ca concentrations of 2-6 g/kg, with higher requirements for lactation have been variously recommended for cattle and sheep (NRC, 1978, 1984, 1985; ARC, 1980), the findings of Sykes and Field (1972) suggest that levels of 2.5-3.0 g/kg are adequate in most circumstances. The results indicate that problems of Ca deficiency would not be expected. It is still widely believed that a large excess of Ca over P, resulting in Ca:P ratios approximating 10 or more, is deleterious to ruminants, although much conflicting evidence occurs in the literature (reviewed by Little, 1970). In this context it is noteworthy that the ARC (1980) concluded that "...it is not possible to state the optimal ratio of calcium to phosphorus for animal performance or whether such a ratio actually exists." Where wide ratios occur, the dietary concentration of P *per se* is almost certain to be inadequate.

Underwood (1981) considered a dietary P level of 1.7 g/kg to be marginal for grazing animals, in essential agreement with work of Little (1980, 1985) which indicated that a figure of 1.4 g/kg should be regarded as minimal for growing cattle. The data in Tables 2 and 4 show that most grasses and crop residues examined were marginal to deficient in P, and supplementation with P is likely to be beneficial. For animals grazing on range, this would best be supplied through incorporation into complete mineral licks or in mixtures with common salt and bone meal. Animals on smallholder units, which may receive some concentrate feeds, may receive adequate P if offered high protein oilseed cakes such as cotton seed cake and noug cake.

McDowell *et al* (1978) considered 30 mg/kg to be a critical level of dietary Zn, although the ARC (1980) has suggested that concentrations of 12-20 mg/kg are adequate for growing cattle. The crop residues may thus constitute a marginal supply of Zn (Table 4); the necessity for supplementary Zn needs to be kept under review particularly for sheep, which require some 35 mg Zn/kg diet (ARC, 1980).

It is commonly accepted that the dietary requirement of cattle for Cu lies in the range 8-14 mg/kg (ARC, 1980; NRC, 1978, 1984). Clearly most of the materials examined will provide a marginal to deficient supply of this mineral. This situation may be even further complicated by high levels of dietary Fe which can be elevated by soil ingestion during grazing. Humpries *et al.* (1981) showed that dietary concentrations exceeding 1 g Fe/kg can profoundly reduce the availability of ingested Cu; relatively slight and doubtless common levels of dietary soil contamination can produce Fe concentrations of this order (Healy, 1973), necessitating the serious consideration of supplying supplementary Cu, either by injectable preparations, oral dosing with copper oxide needles or providing mineral licks containing Cu. In this context it should be remembered that the Cu requirement of sheep is only about 5 mg/kg however, so that the provision of supplementary Cu to this species is much less likely to be required.

It should be stressed that data of the type presented here can provide only an indication of the existence of potential mineral deficiency problems, since animal selectivity usually results in the consumption of material of somewhat higher quality than that of the total available, and conclusive diagnosis must be based on the occurrence of a positive response to supplementary supply of the mineral in question. However, such data are vital in the formulation of critical supplementation experiments, upon which recommendations for practical supplementation regimes should be based.

CONCLUSION

The pasture and crop residues examined had very low crude protein contents, and for increased levels of animal production the primary need is for supplementary protein. The most appropriate means of providing this will vary with local circumstances; protein-rich oilseed cakes or urea-containing blocks are valuable sources where they are available. But there is great potential for encouraging the use of leguminous trees, as well as the establishment of forage legumes as crops or oversown in the pasture.

The minerals most widely present in inadequate amounts are Na, Cu and P, and supplementation regimes involving these elements are very likely to produce beneficial results. There is an urgent need for appropriate experimentation so that soundly-based supplementation packages can be devised.

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EFFECT OF PASTURE MINERAL LEVELS ON EXTENSIVE CATTLE PRODUCTION IN KENYA

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Abstract

Mineral levels of Kenyan pastures were examined with the objective of determining whether they were sufficient to meet the requirements of grazing cattle. Potassium (K) was found to be adequate in the herbage while grazing animals are likely to meet their requirements for iron (Fe) through incidental ingestion of soil. The status of magnesium (Mg) and calcium (Ca) needs resolving because adequacy and deficiency have both been reported. Other minerals were, however, found to limit extensive cattle production because they were deficient particularly in the dry season. These included phosphorus (P), sodium (Na), copper (Cu) and cobalt (Co). There was little information on minerals in the rangelands and further research in this area was suggested. Of the preventive measures recommended, provision of mineral supplements was found most appropriate. It was, however, emphasised that for effectiveness of any mineral nutrition programmes, adequate energy and protein nutrition has to be maintained particularly in the dry season.

INTRODUCTION

In Kenya, as in many developing countries natural pastures are the main source of nutrients for cattle. As a consequence, seasonality in quantity and quality of available herbage has a marked influence on animal productivity. Poor animal performance has usually been interpreted in terms of low dry-matter (DM) intake and inadequacy of energy and protein in the DM (Glover and Dougall, 1961; Abate *et al.*, 1981; Abate, 1985; Abate and Abate, in press). Little mention is made of the effect essential elements have on production mainly because under controlled experimental conditions mineral supplements are normally fed. Yet surveys carried out in the country have revealed mineral deficiencies in Kenyan pastures (Burdin and Howard, 1963; Howard, 1969; Mwakatundu, 1977) with obvious consequences on animal development and reproduction (Todd, 1954; Howard *et al.*, 1962).

This paper aims to examine mineral levels in Kenyan pastures with emphasis on the effect of deficiencies on cattle production.

EARTH LICKS AS SOURCES OF MINERALS

Early indications of mineral deficiency in Kenyan pastures followed observations on earth eating and oesteofagia by cattle and wild ruminants (Todd, 1954; French, 1955; Howard, 1963). Table 1 shows the composition of two such natural licks. Hudson (1944), French (1955) and Howard (1963) concluded from other similar analyses that natural licks contained insufficient sodium

(Na) while the levels of phosphorus (P) and calcium (Ca) were too low to alleviate a deficiency. Concentrations of as high as 15.1 and 78.1% of sodium chloride (NaCl) have, however, been reported in the DM of natural salt licks in parts of North Eastern Province (Hudson, 1944). The availability of mineral elements from earth licks is also probably low since only up to 6% of the organic matter is soluble in dilute acid (Table 1). In spite of their unlikelihood as sources of minerals, cattle owners still regarded such salt licks as essential to the well being of their animals (Hudson, 1944).

Table 1. Mineral composition (% DM) of salt licks from two different areas in Machakos District.

	Emali	Koru
Total organic matter, %	98.6	96.8
Inorganic matter soluble in 0.125N HCl, %	1.8	6.5
Percent DM		
Calcium	0.03	0.80
Magnesium	0.40	0.10
Sodium	0.02	0.10
Potassium	0	Trace
Phosphorus	Trace	0.01
Iron	0.04	0.18
Copper	0.0008	0.001

Source: Hudson (1944).

BORDERLINE TO SUFFICIENT MINERALS

Potassium (K) concentration in Kenyan forages are quite high (Abate, 1984; unpublished data); levels compare well to those in productive grasses elsewhere in the world (Howard, 1963) and are adequate in meeting the requirements of grazing livestock (Howard *et al.*, 1962). Because of large quantities in the soil, animals are also likely to augment their iron (Fe) supplies through direct ingestion of soil or from soil-contaminated herbage (French, 1955; Hodgson *et al.*, 1962) and would, therefore, suffer no deficiency. For some minerals, the risk is either little or there is no evidence of deficiency in grazing animals (French, 1955; Mwakatundu, 1977). Depending on the area, other minerals may be borderline to sufficient. Thus, Howard (1963) has indicated that there may be a need to topdress Kenyan pastures with magnesium (Mg) fertilizers because levels of the element in grazings were similar to those that predispose animals to grass tetany. But Mwakatundu (1977) maintained that Mg was not limiting in Kenya because the element was sufficient in soils, pastures and bovine plasma. Also a suspected case of hypomagnesemia in the Naivasha area was not confirmed by serum analysis (Howard, 1963). The position with regard to Ca equally requires defining. Howard (1963) found Ca levels in Kenyan pastures satisfactory but Mwakatundu (1977) reported that areas in Central and Rift Valley provinces were deficient in the mineral. A national average value of 0.53% has been quoted

(Howard, 1963) although a lower concentration of 0.39% has also been reported for ley and natural pastures at Muguga, Central Kenya (Howard *et al.*, 1962). On account of a comparatively lower productivity, a Ca deficiency is unlikely to occur in beef herds because of the ability to mobilise body depots. A proper Ca:P ratio is, however, physiologically desirable for high fertility and adequate rate of growth irrespective of level of production. Results of studies carried out in Baraton, Egerton, Kabete and Molo suggested that the Ca:P ratios of the grazings were satisfactory for ruminants (Mwakatundu, 1977).

DEFICIENT MINERALS

Based on the available literature, the minerals most likely to limit cattle production in Kenya are P, Na, copper (Cu) and cobalt (Co). Certain trace minerals like selenium (Se) and zinc (Zn) could, however, also be limiting.

Phosphorus

In a mineral survey Howard (1963) reported that 36% of natural pastures analysed contained less than 0.3% P while the average value for the country was 0.41%. Levels were lower in the dry than in the wet season. Todd (1954) analysed samples of *Chloris gayana, Bothriochloa insculpta* and *Brachiaria dictyoneura* and found them to contain as low as 0.13% P in the DM in the dry season. These results were similar to those of Howard *et al.*, (1962) who reported a range in P content of 0.072-0.252% in grazed pastures in the high potential areas of Kenya; at the lower level P was deficient and this occurred during dry spells. Mwakatundu (1977) also confirmed that in Kenya P deficiency was widespread as shown by low levels in soil, pasture and bovine plasma. The concentration of P depended largely upon the extent of recent precipitation and was highly correlated ($r = 0.72^{**}$) to CP levels in the pasture (Howard *et al.*, 1962). Mwakatundu (1977) has reported similar results.

The requirements for P by grazing Kenyan cattle are not known. It is probable, however, that pasture levels of P are sufficient to maintain slow maturing and low producing indigenous animals but is inadequate for high producing improved breeds (French, 1955). Suboptimal P levels in grazings have resulted in the following in Kenyan cattle: loss of appetite hence reduced feed intake, retarded growth, interference with regularity of heat hence reproductive rates, lowered milk production and, in extreme cases, depraved appetite or pica (Howard, 1963).

Sodium

The concentrations of Na in pastures throughout Kenya are very low (Howard, 1963), particularly in the dry season (French, 1955). Wet season grass may, however, also contain Na levels that are insufficient in meeting animal requirements (French, 1955). This is because rapid gain in weight by animals during the wet season induces high mineral requirements (McDowell *et al.*, 1984). Of all pastures analysed in Kenya, 77% contained 0.01% or less Na; levels which are inadequate to cover the demands of dairy and improved beef cattle. A range of 0.007-

0.022% Na has been reported for samples obtained from ley and permanent pastures of *Cynodon dactylon* and *Chloris gayana* in Muguga, Central Kenya (Howard *et al.*, 1962). Severe symptoms of Na deficiency have not been reported in Kenya mainly because most farmers feed salt to their animals.

Copper

Disorders such as stilted gait, rusty coat colour and, in severe cases, fragility of bones in calves have been identified in Kenya as due to Cu deficiency (French, 1955; Howard, 1963). Copper concentrations in Kenyan pastures seem to lie between 4.0 and 12.2 ppm (Howard *et al.*, 1962). Deficiency normally shows itself at levels lower than 5.0 ppm, and this has been shown in about 35% of pastures analysed in Kenya (Howard, 1963). Shortage of Cu has been recorded in grazings along the Rift Valley and in parts of Central and Rift Valley provinces (Howard, 196`) because of a Cu deficiency in the soil (Pinkerton *et al.*, 1965). Soils in which the underlying rock is ash and pumice may be expected to be deficient in Cu (Nyandat and Ochieng, 1976). Mwakatundu (1977) also found subclinical Cu deficiency widespread in Kenya as a result of Cu deficiency either in the soil or pasture or bovine plasma and is more pronounced in dry periods (Nyandat and Ochieng, 1976). The functioning of dietary Cu can be inhibited by excess molybdenum (Mo) resulting in a conditioned Cu deficiency. Animals consuming forages with Mo concentrations above 15 to 20 ppm showed Cu deficiency symptoms even though the Cu levels in the forage were higher than 5 ppm (Hodgson *et al.*, 1962). Conditioned Cu deficiency does not seem a problem in Kenya because Mo was found deficient in several areas surveyed (Mwakatundu, 1977).

Cobalt

Cobalt is a serious mineral limitation to livestock because even when grazing is abundant deficiency will lead to chronic starvation or wasting which is often indistinguishable from energy and protein malnutrition (French, 1952; Howard, 1963; McDowell *et al.*, 1984). It is rare for grasses to contain Co in concentrations that meet the demands of grazing animals (Hodgson *et al.*, 1962). When the content in the pastures herbage is 0.10 ppm or less (Hodgson *et al.*, 1962) grazing animals are likely to suffer from Co deficiency. In Kenya, the condition is known as "Nakuruitis" (French, 1952; Howard, 1963) or as "Narurasha" among Maasai herdsmen (Hudson, 1944; French, 1952). Cobalt deficiency is common along the Rift Valley and is seasonal in character with symptoms usually appearing after the rains when grazing is plentiful and green (Hudson, 1944). Mwakatundu (1977) also confirmed Co deficiency in the Egerton, Kabete and Molo areas of Kenya. Animals suffering from Co deficiency lose appetite and condition, may abort if in calf or may have difficulty to conceive again; the condition seems to affect lactating cows more than any other type of stock (Hudson, 1944; French, 1952).

MINERAL LEVELS IN THE RANGELANDS

The literature cited above refers mainly to mineral deficiencies in the high potential areas of Kenya which are characterised by about 1200 mm of rainfall per annum. Reports on the effects of minerals on animal production in the rangelands of Kenya are lacking.

About 85% of the total land area of Kenya is rangeland unsuitable for arable cropping because it receives only 500-750 mm of rainfall per year. The rangelands are, however, important because they contain about 50% of the total livestock population in the country. The cattle population here consists mainly of low production indigenous stock. In these areas grazing forms the only source of feed and the natural vegetation is dominated by *Commiphora, Acacia* and *Themeda* associations with a carrying capacity of 4 ha to a stock unit.

In Table 2 are given lists of preferred grass species in the rangelands of Kiboko (Hatch *et al.*, 1984) and around Isiolo (Schwartz, H.J. pers. comm.). For most of the year the quality of the herbage is low. Karue (1974) stated that the level of digestible energy for most of the grasses in the dry zones of Kenya is inadequate to meet the demands for maintenance of grazing stock in the wet and dry seasons. Tessema (1986) reported that the grasses of the semi-arid areas of Eastern Province had high proportions of structural carbohydrates which were deposited in the plant tissues at an early vegetational stage; the protein content on the other hand dropped from 11 to 4% at six months of age.

Table 2. Composition of the most important grass species in the rangelands around Kiboko and Isiolo.

Kiboko	Isiolo
Digitaria macroblephara	*Setaria verticillata*
Cenchrus ciliaris	*Sporobolus nervosa*
Themeda triandra	*Aristida adscensiomis*
Chrysopogon plectostachyus	*Eragrostis ciliaris*
Chloris roxburghiana	*Cynodon dactylon*
Eragrostis caespitosa	*Tetrapogon cenchriformis*
Panicum maximum	*Pennisetum mezianum*
Enteropogon macrostachys	*Chrysopogon plumulosus*
Sporobolus fimbriatus	

Sources: Hatch *et al* (1984); Shwartz (unpublished data).

The mineral composition of wet season grasses around Isiolo is given in Table 3. This is compared to the data from high potential areas of Mwakatundu (1977) given in Table 4. The mean values for the range area are comparable to those reported for the high potential areas. The data suggest that wet season grasses in the rangelands of Isiolo contain adequate levels of minerals to meet the demands of grazing animals. Consumption of sufficient quantities may, however, be limited by herbage intake since in the rangelands, CP levels fall to about 7% in only 8-10 weeks (Tessema, 1986).

Table 3. Mineral composition (% DM) of some grass species in the Isiolo rangelands.

	P	Mg	Na	K
	% M			
Pennisetum mezianum	0.17	0.19	0.10	0.62
Setaria vertilillata	0.27	0.41	0.10	2.62
Aristida adscensionis	0.14	0.15	0.11	0.51
Tetrapogon cenchriformis	0.24	0.22	0.14	1.22
Cynodon dactylon	0.44	1.10	0.11	1.86
Eragrostis ciliaris	0.39	0.28	0.10	1.44
Chrysopogon plumulosus	0.16	0.21	0.06	0.69
Sporobolus nervosas	0.40	0.28	0.08	1.21
Mean ± S.D.	0.28±0.12	0.36±0.31	0.1±0.02	1.27±0.27

Table 4. Average mineral composition in the DM of pastures from selected areas of Kenya.

Ca	P	Mg	Cu	Co	Season	Station
% DM			ppm			
0.32	0.24	0.17	7.0	0.142	Wet	Baraton
0.59	0.28	0.24	11.0	0.210	Dry	
0.53	0.35	1.18	14.0	0.061	Wet	Egerton
0.55	0.27	0.17	9.0	0.036	Dry	
0.37	0.45	0.26	7.0	0.142	Wet	Kabete
0.39	0.26	0.10	6.0	0.098	Dry	
0.38	0.16	0.18	8.0	0.086	Wet	Molo
0.53	0.20	0.18	11.0	0.027	Dry	

Source: Mwakatundu (1977).

MEETING MINERAL REQUIREMENTS OF GRAZING ANIMALS

An adequate supply of energy and protein are no doubt important in the maintenance of high productivity in any animal production system. In the rangelands of Kenya benefits would be even greater if in addition, appropriate strategies were adopted to meet the mineral requirements of the grazing animal. McDowell *et al.* (1984) have observed that cattle grazing forages in severe P-Co- or Cu-deficient areas are even more limited by lack of these elements than by lack of either energy or protein.

In the past the practice has been to move cattle to natural earth licks at certain seasons of the year (Hudson, 1944; Howard, 1963), but as has been indicated earlier, the value of such licks as sources of minerals is low since they are devoid of reasonable quantities of either salt, Ca or P. Movement of animals to unaffected areas has been shown to cure Co deficiency (Hudson, 1944). This is unlikely to remain a solution in the future in view of the present increase in population which will take more land for food crop production. Use of mineral supplements on the other hand increased milk yields, produced heavier calves and maintained better animal condition than unsupplemented controls, particularly in the dry season (Howard, 1963).

It is evident from the above observations that there is need for increased attention to be paid to mineral nutrition. Farmers need to be informed that energy, protein and minerals are interrelated in body maintenance, growth and health. They should be made aware of the possible incidence of mineral deficiencies because parts of Kenya are lacking in a number of the mineral elements essential in animal nutrition. Periodic mineral surveys which should include analyses of soil, water, plant and animal tissue are necessary in order to detect inadequacies.

Inclusion of legumes in the pasture provides a mixture that ensures adequate intake of Co by grazing animals because legumes are efficient in accumulating Co in amounts above animal requirements (Hodgson *et al.*, 1962).

A mineral deficiency in pasture herbage is often a result of a deficiency in soil. Thus, the potential role of fertilizers in meeting animal requirements for minerals needs to be studied so as to develop a fertilizer package that is location specific. For example, Cu deficiency in animals may be treated by top dressing pastures with copper sulphate (Hodgson *et al.*, 1962). It should be noted, however, that inadequate or erratic rainfall may be dominant over soil effects in determining the mineral concentrations of the herbage. Individual minerals may be administered as a drench, injection or slow release pellets. The use of "copper bullets" has been recommended for range livestock (Hodgson *et al.*, 1962), but this would require professional supervision.

By far the most important method of meeting requirements lies in mineral supplementation. Economic and physiological responses to mineral supplements have been recorded (French 1955; Howard, 1963), and this should be encouraged through the widespread use of free choice compound mineral licks. Several ranches in Kenya are known to offer mineral licks to their animals although there is no guarantee that all animals will consume enough of the lick at all times. What is desirable, however, is that such mineral mixtures should ensure that levels of P, Na, Cu and Co are particularly adequate. Finally, it is important to note that the measures recommended above are only effective if the general level of nutrition with regard to energy and protein is maintained particularly in the dry season.

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EFFECT OF SEASON, FERTILIZER APPLICATION AND AGE OF REGROWTH ON MINERAL CONTENT OF GUINEA GRASS (*PANICUM MAXIMUM*, SCHUM) AND GIANT STAR GRASS (*CYNODON NLEMFUENSIS*, CHEDDA)

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Abstract

A study was conducted to evaluate the effect of season (wet/dry), age of regrowth (2, 4, 6, 8, 10, 12 weeks) and fertilizer application (with/without NPK) on the mineral content of Guinea grass and giant star grass. Mineral concentrations in both grasses were significantly affected by the main factors and the age of regrowth effects were often modified by both season and fertilizer effects. The concentrations of potassium and phosphorus and that of copper (only during the wet season) declined with age of regrowth. Fertilizer application resulted in increase of potassium and copper concentrations. The levels of potassium and copper in both grasses were lower during the dry season while those of magnesium, zinc, iron and manganese were higher. Despite these fluctuations, the forages contained adequate amounts of all minerals for livestock requirements except for phosphorus, sodium and copper which were deficient. In production systems where the two grasses constitute the main diet of grazing animals it would be necessary to offer supplementary sodium, phosphorus and copper.

INTRODUCTION

All plants depend upon the soil for their supply of mineral nutrients, and grazing ruminant animals obtain the majority of their mineral nutrients from plants grown on these soils. Concentrations of mineral elements in forage are dependent upon the interaction of a number of factors, including soil, plant species, stage of maturity, yield, pasture management and climate (McDowell *et al.*, 1983). Most naturally occurring mineral deficiencies in herbivores are associated with specific regions and are directly related to soil characteristics (Underwood, 1981; McDowell *et al.*, 1983). When mineral nutrients in herbage are marginal in respect of animal requirements, changes in concentrations brought about by climatic, managerial or, seasonal influences as well as plant maturity can be significant factors in incidence or severity of deficiency states by livestock wholly or largely dependent on these plants (Underwood, 1981).

In West Africa, as in the rest of tropical Africa, forages still serve largely as a source of essential elements for grazing animals. Little coordinated research has been done in these areas to identify places of endemic mineral deficiencies and toxicities. Little information is available on the mineral status of grazing animals and of the forages upon which they subsist. Since the mineral status of these forages is a function of multiple factors which interact with one another to produce varied effects, it is vital to investigate how such factors influence the mineral status of different forages in a tropical environment. This study was thus planned to investigate the effect of age of regrowth, season and fertilizer application on the mineral profile of two grasses predominant in the humid zone of West Africa, namely Guinea grass and giant star grass.

MATERIALS AND METHODS

The experiment was conducted at the University of Ife teaching and research farm situated in southwestern Nigeria at coordinates 7°28'N and 4°33'E at an altitude of 240 m above sea level. The average annual rainfall is about 1290 mm and the climate is subhumid. The rainy (wet) season stretches from about April to October while the dry season is from November to March.

Four plots each 10 m x 10 m, two for Guinea grass (*Panicum maximum*, var. S112, Nchisi, Schum.) and two for giant star grass (*Cynodon nlemfuensis* var. *nlemfuensis,* IB8, Chedda) were cut back at heights of 15 and 5 cm respectively during the early wet season and early dry season. On the day of cutting back, one plot for each grass was fertilized with NPK (15-15-15) at the rate of 100 kg/ha. Samples of regrowth cut at a height of 15 and 5 cm for Guinea grass and giant star grass respectively were taken at 2, 4, 6, 8, 10 and 12 weeks after initial cutting back. The samples were harvested from five randomly selected areas (each 1 m^2 in size). The samples were taken to the laboratory, chopped into pieces, mixed and dried at 85°C over night before being ground in a laboratory stainless steel mill using a one-mm sieve. The dried samples were ashed at 500°C for 8 hours and extracted with 6 M HCl as described by Buchanan-Smith *et al.* (1964). Potassium and sodium concentrations in the extracts were analysed by flame photometer while calcium, magnesium, manganese, iron, zinc and copper were determined by atomic absorption spectroscopy. Phosphorus concentration was determined by calorimetry (Fiske and Subbarow, 1925).

Soil samples were randomly taken from the unfertilized plots during both seasons and prepared for mineral analysis as described by Black (1965). The mineral concentrations in the extracts were determined using the same procedures described above.

Data on forage mineral content was analysed, as a 2 x 2 x 6 factorial experiment with two fertilizer application levels, two seasons and six ages of regrowth. Soil data were subjected to one-way analysis of variance. Significant differences between treatment means were tested with Tukey's procedure (Steel and Torrie, 1960).

RESULTS

The results on soil chemical composition indicated the soil pH was acidic (Table 1). Soil total nitrogen and exchangeable potassium and magnesium concentrations were higher ($P<0.01$)

during the dry season than during the wet season. Available P, Ca, Na and Zn were lower (P<0.01) during the dry season than during the wet season.

Table 1. Chemical composition of soils from experimental site at different periods.

	Period of sampling				
	Early wet season	Late wet season	Late dry season	Mean	SE
Soil pH	5.5	5.4	5.9	5.6	0.18
Soil nitrogen (%)	0.28^{b}	0.31^{b}	0.4^{a}	0.3	0.04
Available P (g/g)	55.5^{a}	15.3^{b}	10.4^{b}	27.1	17.68
Calcium (g/g)	1611.7^{a}	1452^{b}	1372.3^{b}	1478.7	87.08
Manganese (g/g)	241.3^{b}	251.3^{b}	287.7^{a}	260.1	17.4
Potassium (g/g)	105.4^{c}	171.9^{b}	212.2^{a}	163.2	38.5
Sodium (g/g)	11.4^{a}	10.6^{a}	8.5^{b}	10.2	1.07
Manganese (g/g)	575	550	525	550	14.7
Iron (g/g)	275^{a}	300	225^{b}	266.7	27.28
Zinc (g/g)	70^{a}	32.5^{b}	12^{c}	38.2	17.30
Copper (g/g)	7.1	6.4	6.1	6.5	0.37

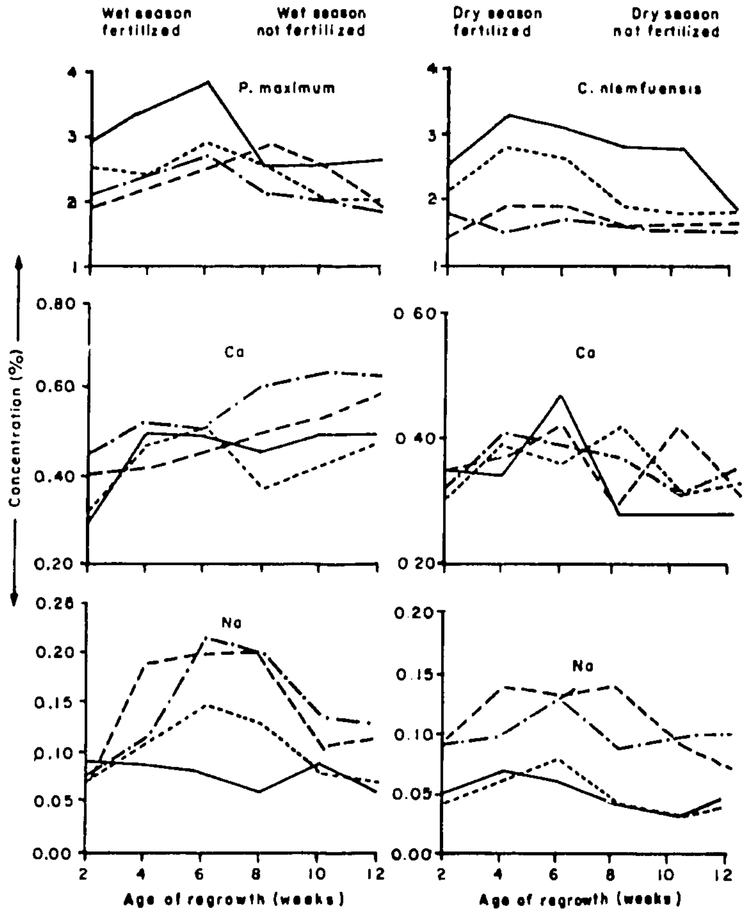
a,b,c in the same row, means bearing different superscripts are different (P<0.01).

Mineral concentrations in both grasses were significantly affected (P<0.0.1) by the main factors. In most cases, the effects of the main factors were dependent on one another. Thus two-way interaction effects were observed for nearly all the minerals. The age of regrowth effects were often modified by both season and fertilizer effects.

The K concentration in both grasses was higher (P<0.01) during the wet season particularly during the early period of regrowth. With both grasses there was a general decline in K concentration after six weeks of regrowth and the concentration of this element was lowest during the dry season though the differences were narrow toward the end of the regrowth period (Figure 1). The concentration of Na in both grasses increased up to four weeks and thereafter the changes were inconsistent. With both Guinea grass and giant star grass, the concentration of Na was higher during the dry season. There was an increase in the concentration of Ca during both seasons in Guinea grass while in giant star grass the changes were irregular and no overall increase was observed over the whole period. Except for K where lower concentrations of the element were observed in unfertilized plots, fertilizer effect on Na and Ca concentrations were inconsistent.

The concentration of P in Guinea grass during both seasons and in giant star grass during the wet season declined with age of regrowth. No remarkable differences were observed due to either season or fertilizer application (Figure 2). Overall,

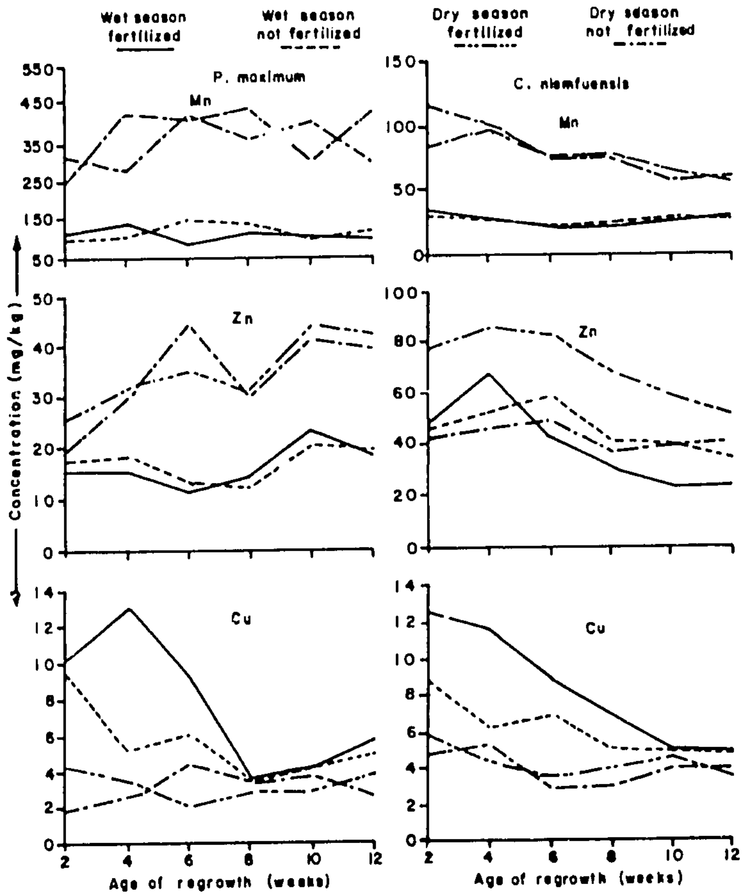
Figure 1. Potassium, calcium and sodium concentrations of *P. maximum* and *C. nlemfuensis* over 12 weeks of regrowth as influenced by season and fertilizer application.



there was an increase with age of regrowth in the concentration of Mg in Guinea grass during both seasons and in giant star grass during the dry season. The concentration of Mg in both grasses was higher during the dry season. Fertilizer application was associated with higher Mg concentration during the dry seasons in giant star grass while the reverse was observed in the case of Guinea grass.

The concentration of Fe in Guinea grass was fairly constant during the wet season but rose sharply with age of regrowth during the dry season. The changes in iron concentration with age of regrowth in giant star grass were inconsistent. Fe concentration was greatly increased by fertilizer application during the dry season. Except for giant star grass during the dry season when there was a decline in concentration with age of regrowth, the Mn concentration in both grasses exhibited slight

Figure 2. Magnesium, phosphorus and iron concentrations of *P. maximum* and *C. nlemfuensis* over 12 weeks of regrowth as influenced by season and fertilizer application.



variations over the 12-week period. In both grasses the concentration of Mn was higher during the dry season. No remarkable differences in concentration of Mn were associated with fertilizer effect (Figure 3). The changes in Zn concentration in Guinea grass during the wet season over the 12-week period were slight while there was a significant increase during the dry season. The concentration of Zn was high in Guinea grass during the dry season and only in unfertilized giant star grass during the same period. There was decline in Cu concentration during the wet season in both grasses with age of regrowth while little variation occurred with age of regrowth during the dry season. Fertilizer application on both grasses during the wet season resulted in higher Cu content.

DISCUSSION

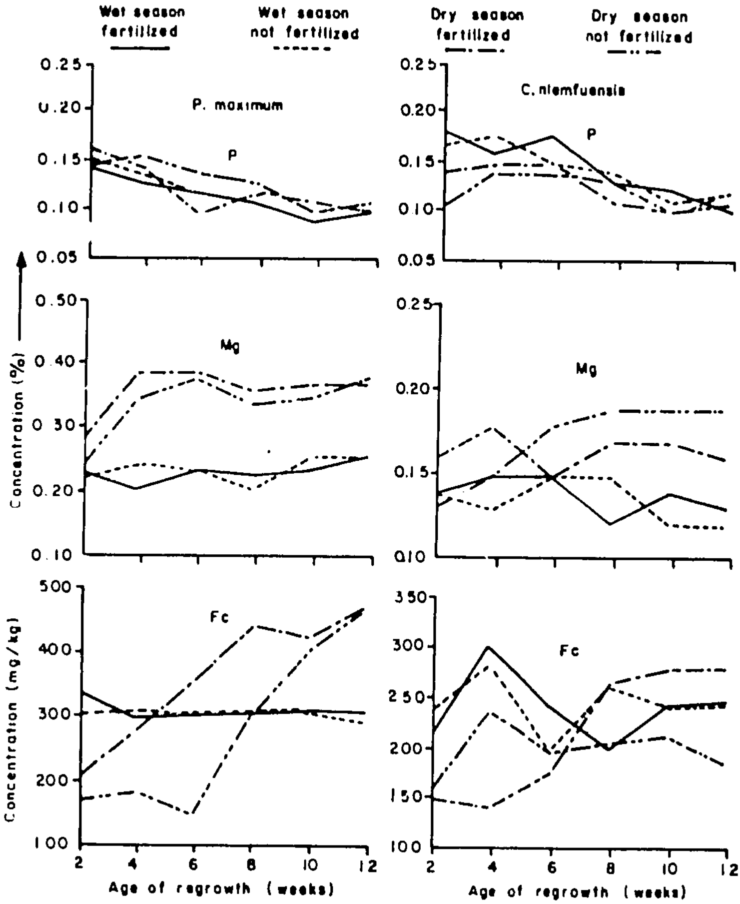
Potassium, phosphorus and copper concentrations declined with age of regrowth. With temperate grasses, Whitehead (1966) observed that P content and that of most trace elements in herbage declined with age. Potassium and P declining with age has been reported in tropical forages (Perdomo *et al.*, 1977; Gomide, 1978). This decline may be due to the effect of dilution of these elements in a great quantity of dry matter that is produced and accumulated with advancing age. Gomide (1978) associated the low concentration of P and K in young tissues to their being mobile and thus easily translocated from the oldest tissues to the young ones.

In this study Na and Ca concentrations in both grasses did not change appreciably with increase in age of regrowth at most times. Perdomo *et al.* (1977) observed that Ca concentration in Guinea grass and Bermuda grass did not change with increasing maturity. They however observed that Na concentration in Guinea grass increased with age. Fleming (1973) observed that Ca levels in forages remained relatively constant with advancing maturity. The concentration of Mg exhibited slight variations with age of regrowth during the wet season but increased during the dry season. Fleming and Murphy (1968) reported that Mg content in temperate grasses exhibited relatively little variation with advance in maturity. On the contrary, Jones (1963) in Zimbabwe noted that Mg levels in Guinea grass decreased with advancing maturity.

Except for Cu, whose concentration declined with age of regrowth during the wet season in both grasses, the changes exhibited by the other trace elements were inconsistent. The decline in Cu concentration with age of regrowth has been earlier reported in temperate grasses (Thomas *et al.*, 1952) and tropical grasses (Gomide *et al.*, 1969). The inconsistencies in changes in trace element concentration observed in this study agreed with the statement by Conrad (1978) that trace minerals in plants may increase, decrease or show no consistent change with stage of growth, plant species, soil or seasonal conditions.

In this study only K and Cu were remarkably affected by NPK fertilizer application. When NPK fertilizer was applied on Guinea grass and giant star grass in central Brazil (Gomide *et al.*, 1969) no effect was observed on any of the minerals studied

Figure 3. Manganese, zinc and copper concentrations of *P. maximum* and *C. nlemfuensis* over 12 weeks of regrowth as influenced by season and fertilizer application.



except Mn, whose concentration increased. Hemingway (1962) found that application of nitrogen fertilizer to grasses increased their Cu content while neither superphosphate nor muriate of potash influenced the Cu content of the herbage. Fleming and Murphy (1968) reported that application of K fertilizers resulted in increased Mg concentration in the herbage while the level of K subsequently increased. In this study, the failure of NPK fertilizer to influence Mg concentration considerably could be due to the combined effect of K and P, as Andrew and Robins (1969) reported that P fertilizer application resulted in increased Mg concentration while K fertilizer caused a reversed effect.

According to NRC (1978, 1984, 1985) mineral requirement recommendations for cattle and sheep, the two forages were adequate in K, Ca, Mg, Mn, Fe and Zn. The latter element was marginal in Guinea grass during the wet season. The grasses were deficient in P, Na and Cu during both seasons. The Cu deficiency was more severe during the dry season. Low levels of Na, P and Cu in tropical forages have earlier been reported (Oyenuga and Hill, 1966; Ademosun and Baumgardt, 1967). Concentrations of Mn as high as 430 mg/kg that were observed in Guinea grass could probably be detrimental to animal health through interference with metabolism of other minerals (Thomas, 1970). Whether such high levels are of any economic significance in Africa is an aspect yet to be investigated.

CONCLUSION

A study of the effect of season, age of regrowth and NPK fertilizer application on the mineral profile of Guinea grass and giant star grass indicated significant effects of the main factors, particularly of season and age of regrowth on almost all the elements. The two grasses were adequate in all minerals measured for livestock feed, except for Na, P and Cu. In case the two grasses are exclusively fed to livestock, it is recommendable to supplement with these deficient minerals. Other measures that could be taken to improve the mineral status of these forages include fertilizer application in case of P, Zn and Cu as well as foliar dusting in case of Zn and Cu as long as precautions are taken not to deposit excess amounts of these minerals on the vegetation. Effectiveness of such corrective measures under African field conditions need to be investigated. In both grasses, the Mn and Fe concentrations occurred in quantities far in excess of livestock requirements. It is recommended that further research be done to elucidate any deleterious effects to livestock that might be associated with such high mineral concentrations.

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RESEARCH NEEDS FOR FORAGE DEVELOPMENT IN ETHIOPIA: THE FOURTH LIVESTOCK DEVELOPMENT PROJECT STRATEGIES

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Abstract

The Fourth Livestock Development Project will be promoting a range of strategies for forage development, namely: establishment of forage strips including bund-planted forages and tree legumes in alley cropping systems; backyard forage development; improvement of stock exclusion areas through the introduction of legumes; the use of forage legumes in undersowing/relay cropping systems; oversowing of grazing areas; and establishment of perennial mixed pastures and annual fodder crops. This paper details the strategies, ranks them in terms of the potential impact within the project area and outlines the perceived priority research programmes required to support these strategies.

The approach to establishing a large forage seed production capacity and the research needs to support this programme are discussed.

The various strategies described have different labour requirements, and the monitoring of labour inputs would be a significant part of the applied research programme.

INTRODUCTION

The Fourth Livestock Development Project (FLDP) is a five-year phased programme designed to build an efficient national animal health service and simultaneously improve animal nutrition in the peasant sector. The primary objective is to improve livestock and agricultural production through increasing the efficiency of resource utilisation at the farm level in both the government and peasant sector cooperative support services. Increasing foreign exchange earnings and decreasing potential ecological damage through increasing live animal and hide and skins exports and through import substitution (dairy produce) is also an important objective. Institution-building within the Ministry of Agriculture represents a major project objective.

The project consists of six main components:

1. Animal health development,
2. Animal feed and nutrition development,
3. Southern rangeland pilot development,
4. Agricultural credit,
5. Institutional development,
6. Live animal trade development study.

The major objectives of the animal feed and nutrition development component of the Fourth Livestock Development Project (FLDP) are:

a) To increase the supply of forage for ruminant livestock in the peasant sector,
b) To conserve soil on arable land and catchment areas,
c) By increasing the quality and quantity of feed; increase livestock meat and milk production,
d) Increase manure production,
e) Increase draft power for cropping,
f) Increase fuel wood and timber supplies.

This paper details with the various Fourth Livestock Development Project strategies and research needs for forage development which will be directed at improving forage production, management and utilisation at farm level.

FACTORS IN DETERMINING THE STRATEGIES

Long-term sustainable production of livestock and cropping is dependent on dramatic changes in livestock management systems. The key components of these changes are a shift towards more intensive feeding systems, with more emphasis on cut-and-carry feeding, and a gradual shift away from uncontrolled grazing, particularly on sloping areas.

The strategies would be integrated closely with cropping practices, and in almost all cases, would avoid displacement of arable crops; in fact, the strategies would generally be complementary to arable cropping. There would be emphasis on the high potential areas, partly because those areas have the greatest potential for increased forage production under the kinds of strategies promoted, and also because most extension staff are being deployed in the high potential cropping areas.

Strong links will be maintained with soil conservation programmes: physical soil conservation works can be substantially improved through the incorporation of improved forages; also, some forage development strategies can have a direct benefit in terms of erosion control, even in the absence of physical soil works. However, strategies would not be dependent on "food for work programmes" as this is not feasible in a programme of the size envisaged, and it would also reduce the likelihood of widespread rapid and spontaneous adoption of some strategies.

There should be strong links with animal health programmes because of the mutual synergism not only in physical production terms, but also in the extension context. The interface between health and nutrition programmes would occur at the service cooperative, which is the major unit for extension.

There would also be close links with the beef fattening and dairy programmes; the widespread success of both these programmes will be largely dependent on the incorporation of sound forage development, and there is also a reverse benefit in that the Project's forage development proposals would be more readily adopted within the peasant sector if they are linked with such programmes, thus offering the opportunity for conspicuous cash benefits.

Legumes would be heavily emphasised because of their dual roles in both animal nutrition and in the maintenance or improvement of soil fertility and hence crop production.

It is imperative that most strategies have a low financial cost if they are to be adopted within the peasant sector; in this context the heavy use of fertilizers would generally be avoided, and beef fattening and dairying programmes should not be dependent on the construction of expensive animal housing or on conventional post-and-wire fencing.

Some strategies at least should have sufficiently conspicuous benefits to facilitate spontaneous and widespread adoption. For instance, the use of tree legumes in some strategies could fit into this category.

It is feasible to initiate a development programme immediately with existing technologies; however, there would be a need for continued adjustment in terms of genetic material and of strategies in the light of newly gained experience from both within the Project and other related institutions. It is imperative that the Project maintain a maximum of flexibility to accommodate these improvements.

The success of various Project interventions will be markedly dependent on the agroecological zone and on other factors including cropping patterns and prior experience with more intensive feeding systems. Whilst the Project would initiate some activites in some of the more difficult areas or systems, it is important that emphasis initially be placed on those areas or production systems affording the best chances of success. Typically these areas would be in the low to medium altitude areas i.e. below 2400 m.

THE STRATEGIES

The development strategies to be promoted by the project are:

a) Strip establishment of forages,
b) Backyard forages,
c) Improved forages in stock exclusion areas,
d) Legumes undersown in crops,
e) Legumes oversown on grazing areas,
f) Perennial mixed grass/legume pastures,
g) Annual fodder crops.

These strategies would generally be associated with an extension programme to improve the utilisation of the forage.

Improved grazing management would be extremely difficult to incorporate into common practice and would generally require substantial reduction in stock numbers to be effective. It will therefore play only a minor role in the development programme.

A significant reduction in livestock numbers could dramatically affect livestock production and land degradation; its potential economic impact is therefore large. However, within current production systems, such a reduction in numbers will not occur in the foreseeable future.

Table 1 illustrates the perceived significance of the various strategies. The potential economic impact, with a score of five representing the maximum impact, is assessed on a basis of increased forage production and benefits in terms of fuelwood supply, erosion control and contributions to the maintenance of soil fertility. The technical possibilities are assessed for low and high altitudes (say, below and above 2200 m), with an indication of acceptance of the strategy amongst farmers or cooperatives. Major research needs in support of the strategies are listed. These are discussed in more detail later.

Table 1. FLDP forage development strategies.

Strategy	Potential economic impact	Technical possibilities Low alt	Technical possibilities High alt	Farmer acceptance	Research needs	Comments
Forage strips (bunds, alleys, etc.)	5	Good	Good	Variable	Species, Mgmt, labour	Stock control, erosion control
Backyard forage	3	Good	Good	Good	Labour	Supplementation
Undersown legumes	2-4	Good	?	Variable	Species timing	Maize/ sorghum
Oversown legumes	0-1	Fair	Low	Good	Species	To 2000 m no control
Exclusion area improvement	4	Good	-	Good	Species	Cut & carry fattening lin':
Conventional pastures	<1	Good	Good	Low	-	Dairy only
Fodder crops	<1	Good	Good	Fair	-	Dairy, fattening
Grazing management	2?	Good	Good	V. low	-	-
Reduced numbers (current systems)	5??	-	-	V. low	-	-

Strip Establishment of Forages

The strip establishment of forages includes:

a) Forages planted on physical soil structures including bunds and terrace walls within arable and stock exclusion areas, but with primary emphasis on the arable areas.

b) Forages planted on contour strips within arable areas, without physical soil structures.

c) Tree or shrub legumes established in parallel strips within crop areas (i.e. in "alley cropping" systems).

d) Forages established in strips around crop plots as shelter belts.

The forage strips would have multiple roles, including the provision of forage for cut-and-carry management, fuelwood supply, soil erosion control and stabilisation of associated crop yields through contributions of organic matter and nitrogen, and through the shelter belt effects.

Tree legumes would form the basis of the forage strips. At higher altitudes grasses (particularly *Phalaris* spp.) would initially predominate in the bund plantings until more reliable tree legumes are available. However, where grasses are used in arable areas, it is important that they are not creeping types to avoid invasion of adjacent crop areas; herbaceous legumes would be incorporated with the grasses where no suitable tree legume is available.

Close spacing of the tree legumes is important for erosion control, but is feasible only with the use of either cuttings or direct seeding; seedlings are too expensive to be used at higher densities. Even at the spacing of 0.5-1.0 metre between plants, costs are substantial, and techniques for improved direct seeding establishment demand immediate investigation.

Management, and particularly the close control of stock access, is crucial to the success of the strategy. Wherever possible, the strips should be reserved for cut-and-carry utilisation; this would greatly enhance persistence and productivity, and the programme should, therefore, be restricted initially to areas where such control is assured. Excess leguminous forage from the strips would be used as a mulch on adjacent crop areas.

The strategy will play an extremely important role in the longer term, but successful demonstration is central to its widespread adoption; initial sites should therefore be selected with good prospects of success.

Farmers have demonstrated fair interest in the strategy, primarily on the basis of increased forage supply; reservations included possible competition effects with adjacent crops and increased difficulty of subsequent cultivation. The latter concern is valid, and the importance of establishing parallel rows wherever possible should be stressed. The importance of establishing a significant visual impact in the first season was clearly demonstrated. Producer cooperatives were shown to be generally much more receptive to the strategy and, where possible, should be used to provide the initial focus for such development.

Backyard Forages

Backyard forage development involves the establishment of plots or hedges of forage in the immediate vicinity of the house. Typically, plots would comprise perennial grass with herbaceous legumes included where possible, or with the grasses interplanted with tree legumes; hedges around the house plots would be of tree legumes or occasionally of tall growing grasses. The inherently higher soil fertility and good control of livestock adjacent to the house enables the establishment of highly productive species with close to maximal yields.

The backyard areas would be used solely for the production of high quality forage for the supplementation of lower quality forage for the supplementation of lower quality feedstuffs including crop residues, particularly in backyard fattening or dairying operations; hence, even small areas of 50-100 m^2 can be significant.

Backyard areas also provide a very convenient point of entry for new species or species types prior to their subsequent use on a wider scale e.g. within the various forage strip programmes. Under the close control offered, farmers can gain an appreciation of both the production potential and of the management requirements of the various species.

Backyard forage is the most readily accepted of all strategies and could be very cost-effective in that it requires relatively little material or extension input. The strategy has already proved to be acceptable and logistically simple in all project areas.

Improved Forages in Stock Exclusion Areas

This strategy involves the establishment of a range of forage species within stock exclusion areas to improve both the productivity of the areas and the feeding value of the forages on offer. Such improvements would greatly enhance the acceptance of the exclusion strategy locally. Major emphasis would be on the herbaceous legumes, because of their contribution to forage quality and to total production, in some cases even under low soil fertility, and because of their relative ease of establishment even on unprepared seedbeds. The grasses typically require much better seedbed preparation for successful establishment, and their use would be largely restricted to sites with recent soil disturbance (e.g. where soil bunds have been constructed within the exclusion areas). Also, the productivity of most exotic grasses would initially be very low in such severely degraded environments; substantial fertility accretion would be expected after several years of active legume growth, whereupon improved grasses could be gradually introduced. The tree legumes would generally have only a minor role within the exclusion areas unless they are encompassed in a broader tree planting programme. The low soil fertility prevalent in such areas is inadequate to support high growth rates of more productive tree legumes such as *Leucaena* sp.

At higher altitudes there are commonly a number of well adapted native legumes present, and currently there is a lack of very useful exotic material for this niche. The programme would be restricted mostly to the low to medium altitudes, where there is often a dearth of useful herbaceous native legumes and for which there are a number of exotic legumes available which are readily established and capable of relatively high productivity even under low soil fertility.

The legumes introduced would include *Macroptilium atropurpureum* and the freer seeding *Stylosanthes* species, with *Desmodium* species also on more favourable sites. The use of grasses would generally be restricted to hardier species such as *Cenchrus ciliaris* and *Paspalum plicatulum*.

In general the forage improvement should be concentrated on peripheral areas of the exclusion zone adjacent to settlement to afford most efficient utili sation by cut-and-carry, and in such cases moderate seeding rates could be used. In more remote parts of the zone, either very low seeding rates or strip planting should be employed to allow a gradual improvement of the sward with increasing proportion of the legume component over several years.

It will be desirable to improve the area as soon as possible after preventing stock access to increase acceptance amongst local users. Areas could be used for cut-and-carry immediately after stock exclusion without seriously reducing the erosion control benefits, and this could also be a significant factor in increasing local acceptance of the strategy. There is an urgent need to define a policy for utilising the woody regrowth on stock exclusion areas; allowing utilization of these woody species would maintain the forage producing potential of the area for a longer period and through meeting another community need could be a key factor in the long-term viability of the exclusion areas.

Undersowing

In this strategy forage species are introduced into an annual crop by sowing after the crop is established. There are several purposes:

1. As a means of establishing a longer term pasture in which case a grass may be included,

2. To improve the grazing value of the crop stubble and of the subsequent fallow,

3. To improve or maintain soil fertility,

4. To provide an additional grain legume for human consumption, in addition to forage.

Initial emphasis would be on the low to medium altitude areas for reasons similar to those given for the stock exclusion strategy i.e. a relative dearth of legumes in these areas and a range of suitable exotic legumes available. Most work will be undertaken initially on the pasture/forage type legumes. Desirable characteristics for undersown legumes include deep rooting/drought tolerance to enable the legume to continue growth after the annual crop has been harvested; retention of leaf and hence of feeding value during the dry periods, to maintain a higher feeding value of the stubble; ease of establishment and heavy early seeding, to allow adequate regeneration in subsequent cropping cycles; and a proportion of hard seed, so that in subsequent crop cycles there is adequate seed remaining in the soil for establishment after the final weeding of the annual crop.

The maize and sorghum systems provide the best opportunities for the strategy, and development can be initiated in such systems without further evaluation. Promising species include the free seeding *Stylosanthes* species including *S. hamata* and the Graham cultivar of *S. guianensis*; the climbing legumes include *Macroptilium atropurpureum, Macrotyloma* spp, and *Desmodium* spp., and the dual purpose types such as *Lablab purpureus*.

An opportunity also exists in some of the higher altitude areas for the introduction of legumes with a longer growing season than the native species. *Trifolium repens* and *Trifolium subterraneum* are likely prospects. The best opportunity appears to be in the *belg*-grown barley system.

The initial sowing would take place after the final weeding, by which stage it is unlikely that the growth of most legumes would offer substantial competition to the companion crop. Sowing rates would be typically quite low, unless the seed is to be harvested for human food or as a cash crop. The strategy does present opportunities for seed collection for some species including *Lablab*.

Potentially useful food grain species which will be incorporated in the programme at least for further evaluation include *Phaseolus acutifolius, Lablab*, and cowpeas. The use of the biennial or short-lived perennial *Cajanus cajan* (pigeon pea), which could be interplanted with a range of crops in an alley cropping type system, offers similar benefits, and the Project is expected to participate vigorously in the wider promotion of this species.

Undersowing was attempted on a range of sites during the 1986 season. It is evident now that the strategy will be quite well accepted by farmers. The strategy is relevant to both the well managed row planted crops characteristic of Hererge, and also to the very poorly managed, weedy crops e.g. in parts of the Rift Valley. In the former case, attempts would be made to link undersowing to contract seed production where possible, at least initially; in the latter case emphasis would be on hardier, self regenerating species.

Legumes Oversown in Grazing Areas

Grazing areas could be improved if it were possible to introduce more productive or better quality species. Such species would need to be adapted to prevailing grazing pressures and soil fertility and to establishment without any land preparation. Grasses are generally unsuitable because the establishment rates of the oversown grass seed on compacted grazing areas are generally extremely low; legumes are generally more suited to such establishment.

The higher altitude areas are typically served by a wide range of useful native legumes, with the *Trifolium* and *Medicago* spp. dominating; other useful species may be identified for this niche, but it is not a priority programme.

At lower altitudes there is a relative dearth of productive herbaceous legumes in the grazing areas, with most of the trailing types having disappeared under the heavy grazing pressures. Also, there are some exotic species which are capable of filling this niche. The genus with the best prospects is *Stylosanthes*, which is typified by ready establishment on poor seedbeds and very low fertility soils, and in many cases by tolerance of extreme grazing pressure. *S. hamata* and *S. scabra* are the most promising species at this stage. Some less palatable climbing species including *Calopogonium mucunoides* will also be usefully oversown in some higher rainfall areas of the western slopes.

Because of the low productive potential, the strategy must be based on very low inputs; in particular, seeding rates should be extremely low.

A modification of the oversowing strategy is the sowing of seed on road verges. This can be done very quickly, is simply monitored, providing a long transect for evaluation and will often enable maximal spread of seed to surrounding areas.

Because of the relatively low establishment rates from oversowing, even with legumes, the programme would be undertaken only on a pilot scale in the first couple of years. Although in suitable areas it can be highly cost-effective.

Oversowing requires minimal inputs of local labour and no management inputs; therefore, there will be no difficulties in promoting the strategy. During the first two seasons the limited areas sown under the programme would be closely monitored to more closely define the site parameters indicating suitability for oversowing.

Establishment of Mixed Grass/Legume Pastures

This strategy involves the establishment of perennial mixed pastures on prepared seed beds and with management including grazing control and fertilizer inputs as required to maintain high productivity. Good arable soils are required for such productivity, and the strategy typically represents a diversion of land from arable cropping. Hence, there is a considerable opportunity cost. Other costs include fertilizer, seed costs (seed inputs would generally be higher than with most other strategies), stock control costs whether for fencing or additional herding labour and weed control. Also, successful management of mixed pastures for high productivity of grazing stock requires considerable skills. The strategy would generally be confined to the dairy programme, but in some cases could encompass the rehabilitation of crop areas through the use of a moderately long-term pasture phase. There are no serious technical constraints in any altitude zone.

The strategy presents an opportunity for occasional seed production, particularly for the grasses, because areas established would generally be of sufficient size to warrant the necessary close supervision of harvest.

Establishment of Short-Term Fodder Crops

The establishment of fodder crops such as alfalfa, oats, vetch and fodder beet will be technically feasible in most altitude zones. The strategy provides a convenient, simple introduction to the concept of actually growing forage for livestock feeding.

Yields may be high in all altitude zones. However, the strategy would not be heavily emphasised in the project for several reasons: The project aims at integrating forage development with erosion control, but excessive use of short-term forage crops may actually aggravate soil erosion through repeated cultivations. Farmers cultivating an area of land would typically establish a subsistence or cash crop and would be reluctant to regularly invest such labour in short-term fodder cropping. The requirement for repeated inputs of seed is a further disincentive. The annual fodder crops may meet short-term needs, but often the perennial species (including some grasses and tree legumes) provide forage over a longer period.

The establishment of short-term forage crops would be confined mostly to the dairy programme. There will be some use of the strategy also in backyard areas, especially with very productive species including alfalfa and fodder beet. Oats could become more widely grown particularly because of its broad adaptation and its dual-purpose nature; it would generally be grown in association with vetch.

SEED PRODUCTION

General Comments

The seed production programme outlined for the Project is large scale by any standards; by Year 4, the Project will need to produce more than 150 tonnes of herbaceous legume seed annually. Also, the programme encompasses a much wider range of species than is usual within a single project. The forage development programme is entirely dependent on the seed production activities. The strategies for production are crucial, and, clearly, strategies previously employed are entirely inadequate for a programme of this scale. The only feasible approach is to produce seed in contract systems.

A programme has already been initiated to collect seed at contract prices from some areas previously established to various forages, including *Leucaena, Sesbania, Lablab,* and vetch. Some indication of the suitability of the various contract prices will be afforded by this initial programme. To obviate the need for importation of large quantities of seed, some irrigated seed production areas have been established in collaboration with the Ministry of State Farms, Institute of Agricultural Research, ILCA and various service cooperatives; however, most production would be under rainfed conditions to facilitate cheaper seed.

The Contract Seed Production Pr.gramme

The great majority of seed must be produced under contract arrangements (with service cooperatives, producer cooperatives and individual farmers), if the overall programme is to succeed. Contract systems, wherein producers are paid contract rates per quantity of clean seed produced, will result in much greater volumes of seed at significantly lower cost per kg, higher production per unit area, much greater efficiency of production, and after the first couple of years, quite reasonable predictability of total seed output.

The contract prices will be set annually though for many species there will be minimal or no change from one season to the next; these prices must be standardised through the Project area and must be valid for at least one production season. The prices will reflect the seed yield potential, labour requirements and potential returns from alternative crops on the same areas. The prices should encourage close attention to management and high recovery of available seed. If the scheme is to succeed within the given time frame, the prices will offer substantially higher returns than for most competing crops. However, because of the relatively small area involved to meet the Project's demands, there would be no disruption of crop production. There are essentially three broad systems which might be used within the contract programme.

For Some Grasses

The Fourth Livestock Development Project (FLDP) would assist dairy cooperatives to establish significant units of grass-based pasture with the understanding that a portion of the area would be closed for a period for seed production, with the cooperative providing harvesting labour under supervision and receiving contract prices. The system is convenient because it offers the chance for larger areas to be harvested, thus facilitating the supervision which is necessary for the harvesting of most of the grasses and overcoming the organisational problems associated with the typically lower seed yields of the grasses.

Seed Collection from Stock Exclusion Areas

Some species will seed quite well on relatively poor sites even though their dry-matter production may be quite low. Therefore, the stock exclusion areas provide a good opportunity for collecting substantial quantities of seed from herbaceous and tree legumes. Most labour would be provided by women and children.

Seed Production on Specialised Plots

Species with high yield potential, and those with high labour and management requirements, may often be best grown on specialised seed production plots. Some of these would be small plots operated by individual farmers. Species suited to this general category include *Stylosanthes* spp., *Lablab* and other climbing legumes grown in trellis systems.

FLDP RESEARCH NEEDS

General

Pasture/forage research programmes require substantial modification to adequately meet the demands of FLDP and similar projects. In particular, there could be less emphasis on evaluating species for conventional pasture development, and more emphasis on species and establishment requirements for specific strategies, and for some of the more difficult but very important systems including stock exclusion. The continued analysis of nutritive value of introduced commercial cultivars, and of the material already comprehensively analysed elsewhere, represents a serious misallocation of research resources.

Species Screening

The Project is servicing a very wide range of environments, and information on species performance from just a few sites may be quite misleading.

There is still inadequate information on the agroecological range of the species which would be used initially within the project. In particular, knowledge on the altitude limits is imprecise. The Project will adopt the approach of using the most promising species/cultivars in the development programmes, with continuous monitoring and refinement; additionally, new material will be continually introduced for rapid screening. Evaluation will be introduced for rapid screening. Evaluation will be undertaken on sites representative of target areas. For example, those species expected to be used in the improvement of stock exclusion areas would typically be assessed on degraded soils of low phosphate status.

Persistence of species must become one of the major criteria in selection. Given the scale of the Project, seed production potential should be granted more emphasis.

There is a particular need to define a wider range of tree legumes suited to intensive cut and-carry-management, in particular for use in higher altitude areas where there is a relative dearth of such species.

Site Assessment

It is crucial that field extension staff be in a position to categorise sites according to suitability for various species and strategies. During the first two years of implementation, some 150-200 service cooperatives will be incorporated, covering a very wide agroecological range. By the end of that period, rapid assessment formulae should have been developed, utilising the key determinants of production including altitude, rainfall and soil factors such as drainage, depth, pH and phosphate status.

Fertilizers will definitely not be used extensively for forage production within the peasant sector in the foreseeable future, and currently there is excessive research on the use of fertilizers for forage production. It is more valid to concentrate on defining site criteria which will determine the success strategic of species. Some research is justified on the use of phosphate (and other nutrients) in seed pelleting as an aid to the Project distributed pelleted seed.

Inoculation

Inoculation requirements for the key species demand urgent attention, and the most convenient media for local use should be assessed. Substantial quantities of inoculant will be required for at least 5-10 species, and it must be determined whether a local production capacity is justified.

Seed Production

It is crucial to collect information on production, harvesting and post-harvest handling for commercial quantities of seed. This will be done by close monitoring of the Project's seed production activities rather than in specific research programmes. It is particularly important to determine likely yields and labour inputs to define optimal prices for the contract seed production programmes.

Propagation of Tree Legumes

The development programmes are heavily dependent on the use of tree legumes, particularly for the more intensive cut-and-carry systems. Current propagation techniques within nurseries are excessively expensive, and there is an urgent need to define systems appropriate to the use of direct seeding cuttings and bare root/bare stem seedlings, enabling the use of small backyard nursery plots.

Economic Aspects

There is an urgent need to undertake economic evaluation of the use of fertilizers within various production systems. This can be done immediately with the wealth of nutrient response data already available. After the first couple of years of the Project, there will be sufficient data for a comprehensive economic analysis of the various strategies. This is particularly important in the case of those strategies with high labour inputs, such as backyard forage and alley cropping.

Also, it is crucial to assess the economics of backyard fattening and dairying using various feed inputs. It is expected that labour requirements for forage collection and forage yields will be central to the economic viability of the strategies; FLDP will allocate adequate resources for determining these parameters during the first two years.

Studies should be undertaken immediately on the feasibility of inducing a shift away from grazing and towards more intensive cut-and-carry systems involving total stock control in the context of peasant associations, producer cooperatives, service cooperatives and larger administrative units.

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